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The origin and significance of carbonaceous matter within Palaeoarchaean marine environments of the Barberton Greenstone Belt, South Africa

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Abstract

Palaeoarchaean (3.6-3.2 Ga) cherts are commonly associated with hydrothermal activity and retain evidence for an early biosphere. They are rich in disordered carbonaceous matter (CM) whom origin cannot be readily associated to biological activity. This project investigate CM-rich material from the BARB3 core obtained from the c. 3.4 Ga old Buck Reef Chert (BRC) of South Africa, one of the best preserved volcano-sedimentary succession on Earth. CM from the core is characterized through a multiple analytical approach based on *in situ* complementary techniques. The aim was to reconstruct the CM origin and evaluate its biogenicity. Samples from the BARB3 shallow-platformal lithofacies, are rich in CM occurring within: (i) crinkly laminated chert; (ii) massive black chert; (iii) laminated black chert; and (iii) granular carbonaceous chert. These four facies bear a specific CM microtextures related to their depositional history. The crinkly laminated chert has a planar stromatolitic-like fabric and include CM mat-like laminae and grains. The massive black chert is structureless and include "cloudy" diffuse CM, CM grains and bitumen-interstitial CM originated as a fluid phase. The laminated black chert include CM grains and the granular carbonaceous chert is a mixture of carbonaceous detritus generated by the hydrothermal brecciation of soft crinkly laminated sediments and it is associated to botryoidal-quartz stratiform veins. The structural characterization of such CM microtextures by means of Raman spectroscopy and HRTEM analyses have confirmed their consistency with the BGB regional metamorphic imprint. However a between-facies and, more importantly, a betweenmicrotexture structural heterogeneity occur guiding the reconstruction of the CM and of the depositional facies history. The result is a revisited picture of the BRC as a shallow-water hydrothermal field characterized by complex microbial communities and carbon remobilization now expressed by multiple CM generations.

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Chapter 1

General introduction

1.1 Origin of carbonaceous matter in modern and ancient sediments

Since life has become well established on Earth it has played a leading role in the global carbon cycle as every known organism needs carbon for its structure or metabolic processes. Photosynthesis, aerobic and to minor extent anaerobic respiration represent the principal pathways by which carbon is processed on the modern Earth (Ellis-Evans, 2011). The biological fixation of carbon greatly affect the element global budget as the remains of dead organisms get buried within sediments resulting into carbon being sequestered in the geosphere where it can be found in the form of amorphous carbonaceous matter (CM).

In meta-sedimentary rocks CM is a typical component and occurs as discrete particles, laminae, clots, or, more often, as diffusely distributed matter within the hosting mineral matrix (Walsh, 1992; Walsh and Lowe, 1999). It consists mainly of sp²-bonded carbon structures containing minor amounts of hydrogen and other heteroatoms including oxygen, nitrogen, sulphur and phosphorus, and it originates from both, albeit rare, non-biological carbon precursors and biological organic matter (OM) (Olcott Marshall et al., 2014). Heating of inorganic compounds, inorganic precipitation from hydrothermal fluids, serpentinization, Fischer-Tropsch-type synthesis and siderite decomposition are among the processes which account for abiotic formation of CM in rocks (Olcott Marshall et al., 2014; Delarue et al., 2016). In contrast, the maturation of biological organic matter and organic debris within sediments during burial, diagenesis and metamorphism accounts for the vast majority of CM in meta-sedimentary rocks (Wopenka and Pasteris, 1993). Such evolution, including early carbonization and later graphitization (Jehlička et al., 2003; Delarue et al., 2016), represents a "defect removal" process during which amorphous organic compounds are gradually deprived of hydrogen, nitrogen, oxygen and other heteroatoms, while the formation of sp²-carbon bonds and hexagonal aromatic rings is promoted (Pasteris and Wopenka, 1991; Ferrari and Robertson, 2000; Jehlička et al., 2003). The original OM is thus progressively reorganized into graphene-like layers, which become stacked together in a trend that, from completely amorphous material, moves towards an ideally pure, crystalline graphite lattice. Because this evolution depends largely on the pressure-temperature (P-T) metamorphic conditions and on the original carbon precursor (Yui et al., 1996; Beyssac et al., 2002), the degree of disorder and the heterogeneity of incompletely reacted CM species in meta-sedimentary rocks can give us insights into the metamorphic history of CM-bearing strata and help to identify the carbonaceous precursor (Yui et al., 1996; Ferrari and Robertson, 2000; Marshall et al., 2012).

On the modern Earth the connection between CM production and biological activity can be readily inferred. This become less obvious for the early Earth CM fossil record because our understanding on the impact of life during the Archaean, between 4 and 2.5 Ga ago, is still hazy. This is for several principal reasons: (i) unequivocal evidence for Archaean life is scarce (Schopf et al., 2007) and both the rate and pathways of ancient OM matter production remain poorly understood; (ii) ancient CM is frequently strongly altered during metamorphic overprints; and (iii) diffuse hydrothermalism through an ultramafic substrate, a suitable setting for the abiotic production of CM, appears to have been widespread on the early Earth (Brasier et al., 2006; Hofmann, 2011). Furthermore, impactors in the form of both carbonaceous chondrites and micrometeorites would have delivered much exogenous CM to the Earth (Maurette et al., 2006). Therefore the assumption for a biological origin of CM in ancient rocks requires caution. Still, most of the earliest evidence for life on Earth occur as microbial carbonaceous remains or as microbialites within Archaean meta-sedimentary rocks generally enriched in CM (Altermann and Kazmierczak, 2003; Schopf et al., 2007; Wacey, 2009; Tab.1.2). Verifying the biogenicity of such CM has long represented a crucial target for the early life investigators and much energy has been directed to reconstruct possible connections between ancient CM production and the early microbial biosphere.

1.2 The earliest geological and fossil record on Earth

When directly investigating the most ancient microbial life, geologists and geobiologists find their first obstacle in retrieving suitable rocks where the early evolution can be studied and reconstructed faithfully. This problem rises as billions of years of plate tectonics have inevitably affected our planet earliest rocks resulting into a scattered, deformed and often highly-metamorphosed ancient geological record. The oldest rocks found on Earth today belong to the Eoarchaean Era (~4-3.6 Ga ago) and consist of high-grade gneiss terranes which have experienced at least amphibolite facies regional metamorphic grade (Nutman *et al.*, 2001; Kranendonk *et al.*, 2007; Ogg *et al.*, 2016). They include primarily plutonic complexes of TTGs (Tonalite–Trondhjemite-Granodiorite) and minor successions of volcanic and metasedimentary units, such as those found in Canada and Greenland (Tab. 1.1). Although tangible, this very first geological window of early Earth processes is problematic especially with concerns to life investigation as the volcano-sedimentary successions, often of dubious interpretation, are scarce, deformed and metamorphosed to a grade at which individual units are difficult to trace and primary evidences of life would be altered beyond recognition. **Table 1.1** - Principal locations of the Earth oldest supracrustal rocks. Eoarchaean rocks are represented mainly by plutonic rocks and scarce meta-sedimentary rocks of dubious origin. Field correlations and depositional reconstructions are particularly difficult in these highly metamorphosed and deformed terrains. This results in the claims for Eoarchaean life to be very contradictory. References for each locality: (1) (lizuka *et al.*, 2007); (2) (Komiya *et al.*, 2015); (3) Harley and Kelly, 2007; (4) (Nutman *et al.*, 1993); (5) Mojzsis and Harrison, 2002; (6) Nutman *et al.*, 2007; (7) O'Neil *et al.*, 2012; (8) Lowe and Tice, 2007.

Name	Area	Lithologies	Age (Ga)	Metamorphic grade
Acasta gneisses ⁽¹⁾	NW Canada	TTGs, volcanic and sedimentary rocks	4.03 - 3.94	Amphibolite
Nulliak supracrustal rocks ⁽²⁾	NE Labrador (Canada)	volcanic and sedimentary rocks	>3.95	Granulite-Amphibolite
Uivak gneisses ⁽²⁾	NE Labrador (Canada)	granitic rocks	>3.95	Granulite
Napier complex ⁽³⁾	Antartica	TTGs, volcanic and sedimentary rocks	3.95 - 3.8	Granulite
Amitsoq complex ⁽⁴⁾	SW Greenland	TTGs and granitic rocks	3.9 - 3.6	Amphibolite
Akilia island ⁽⁵⁾	SW Greenland	TTGs, volcanic and sedimentary rocks	3.83	Amphibolite
Isua belt ⁽⁶⁾	SW Greenland	TTGs, volcano-sedimentary successions	3.8 - 3.7	Amphibolite
Nuvvuagittuq belt ⁽⁷⁾	Northern Quebec (Canada)	TTGs, volcano-sedimentary successions	3.8	upper Amphibolite
Pilbara craton greenstone belts ⁽⁸⁾	Western Australia	TTG, volcano-sedimentry successions	3.53 - 3.31	Greenschist
Barberton greenstone belt ⁽⁸⁾	South Africa and Swaziland	TTG, volcano-sedimentry successions	3.5 - 3.2	Greenschist

Table 1.2 - Principal claims for life in Palaeoarchaean cherts or highly silicified deposits from the Pilbara Craton (Australia) and the Barberton Greenstone Belt (South Africa and Swaziland). All listed deposits are rich in CM however not always carbonaceous body fossils (CM microfossils) have been reported. Environments have been typically interpreted as shallow-marine; often hydrothermalism is involved. The age of the claims is expressed in millions of years. Fm: Formation; PS: Pilbara Supergroup; BGB: Barberton Greenstone Belt.

Age	Geological unit	Environment	Claims for life	References
3496	Dresser Fm, Warrawoona Group, PS	shallow-marine hydrothermal	domical microbialites CM microfossils	Ueno <i>et al.</i> , 2001; Van Kranendonk, 2006; Noffke <i>et al.</i> , 2013
3470	Mount Ada Basalt, Warrawoona Group, PS	shallow-marine	planar microbialites CM microfossils	Awramik <i>et al.</i> , 1983; Schopf <i>et al.</i> , 2007
3465	Apex chert, Warrawoona Group, PS	marine hydrothermal	CM microfossils	Schopf, 1993
3460	Hooggenoeg Fm, Onverwacht Group, BGB	shallow-marine	planar microbialites CM microfossils	Walsh, 1992; Hofmann, 2000; Westall <i>et al.</i> , 2006; Glikson <i>et al.</i> , 2008
3450	Josefdal Chert, Onverwacht Group, BGB	shallow-marine hydrothermal	planar microbialites	Westall et al., 2006, 2015
3440	Panorama Fm, Warrawoona Group, PS	shallow-marine hydrothermal	conical microbialites CM microfossils	Hofmann, 2000; Westall et al., 2006
3426	Strelley Pool Chert, Kelly Group, PS	shallow-marine	planar microbialites CM microfossils	Sugitani <i>et al.</i> , 2015; Duda <i>et al.</i> , 2016
3400	Strelley Pool Chert, Kelly Group, PS	shoreline	CM microfossils	Allwood <i>et al.</i> , 2006; Wacey, 2010
3388	Strelley Pool Chert, Kelly Group, PS	shallow-marine	planar microbialites CM microfossils	Schopf et al.2007
3320	Kromberg Fm, Onverwacht Group, BGB	shallow-marine	planar microbialites CM microfossils	Walsh, 1992; Westall <i>et al.</i> , 2001; Kremer and Kaźmierczak, 2017
3316	Buck Reef Chert, Onverwacht Group, BGB	shallow-marine	planar microbialites	Tice and Lowe, 2004, 2006a,b
3260	Swartkoppie Fm, Onverwacht Group, BGB	shallow-marine	CM microfossils	Knoll and Barghoorn, 1977
3245	Sheba Fm, Fig Tree Group, BGB	shallow-marine	columnar microbialites CM microfossils	Schopf and Barghoorn, 1967; Byerly <i>et al.</i> , 1986
3240	Kangaroo Caves Fm, Sulphur Spring Group, PS	deep-marine hydrothermal	CM microfossils	Rasmussen, 2000
3225	Clutha Fm, Moodies Group, BGB	shallow-marine	CM microfossils	Javaux et al., 2010
3200	Dixon Island Fm, Cleaverville Group, PS	deep-marine hydrothermal	planar microbialites CM microfossils	Kiyokawa et al., 2006

This means that even if signs of microbial activity were originally present those are now prone to equivocal interpretations. Moreover it has been demonstrated that hydrothermal activity, widely diffused on the early Earth (Van Kranendonk, 2006; Hofmann, 2011), and metamorphic processes may generate morphological or chemical features possibly misinterpreted as biological in their origin (García-Ruiz *et al.*, 2003; Brasier *et al.*, 2006; Wacey, 2009; Gargaud *et al.*, 2013). As a result, claims for life from the very first geological record are extremely controversial and putative biological evidence tend to be weakly supported, failing in passing several biogenicity criteria (García-Ruiz *et al.*, 2003; Brasier *et al.*, 2006; Wacey, 2009; Gargaud *et al.*, 2013). This suggests that extreme caution should be taken when interpreting such ancient material. The problem is well exemplified by the process of the "run" for the oldest microfossil, that may results into claims for life, which, in spite of "making it" to the public news, are far from a scientific consensus, providing insufficient support to justify such ancient and important claims (Nutman *et al.*, 2016; Dodd *et al.*, 2017; Tashiro *et al.*, 2017).

Although the biogenicity dilemma recurs constantly in the search for early life, this can be better tested in the Palaeoarchaean (3.6-3.2 Ga ago) record. From this Era well-preserved supracrustal successions of low-metamorphic grade can be found in the cratons of Kaapvaal and Pilbara (Hofmann and Bolhar, 2007; Kranendonk *et al.*, 2007; Wacey *et al.*, 2009; Arndt and Nisbet, 2012; Tab.1.1).Those represent the ideal geological record for a reliable reconstruction of the early Earth processes including life.

1.2.1 The Pilbara and Kaapvaal cratons

Representing the oldest terrains of true continental size in the geological record, the coeval cratons of Pilbara in Western Australia and Kaapvaal in southern Africa share a suite of lithologies and structural affinities which make geologists believe they were once part of a single supercontinent called Vaalbara (Zegers *et al.*, 1998). Formed between about 3.6 and 3.1 Ga ago, they consist of three principal structural components: (I) granitoid-gneiss terrains composed mainly of TTG magmatic complexes; (II) volcano-sedimentary supracrustal successions both pre- and post-dating different phases of TTGs; and (III) late intrusive granitoids (Gargaud *et al.*, 2013). Of those main structural constituents, the volcano-sedimentary sequences from both cratons represent the most celebrated cradles of life on Earth (Altermann, 2001; Altermann and Kazmierczak, 2003; Schopf *et al.*, 2007). They make up elongated structures, wrapped and intruded by earlier and later granitoids, which, in reason

of their characteristic greenschist low-metamorphic grade, are called Greenstone Belts. These true¹ Archaean Greenstone Belts preserve a range of depositional settings which goes from deep-basin and shallow-marine environments characterized by intense extrusive ultramafic-mafic magmatism, hydrothermal activity, silicification and by the precipitation of authigenic sediments such as cherts and banded iron formations (BIFs), to shallower, coastal-deltaic, fluviatile sub-aerial environments observed typically in the upper part of the belts and typified by less abundant, more acidic volcanic rocks and detrital, siliciclastics deposits (Lowe and Byerly, 1999a; Eriksson and Simpson, 2000; Bolhar *et al.*, 2005; Van Kranendonk, 2006; Kranendonk *et al.*, 2007; Hofmann and Bolhar, 2007b; Hofmann and Harris, 2008a). Multiple habitats where chemosynthetic and photosynthetic microbial life could have evolved and flourished are thus represented in this ancient geological record.

In Western Australia the oldest sedimentary rocks are found in the 3.5-3.16 Ga old East Pilbara Terrane (Hickman, 2012). Here vestiges of life in the form of possible microfossils, microbial mats and recurring microbialites have been reported from the numerous greenstone belts grouped in the Pilbara Supergroup (Van Kranendonk, 2007) (Tab. 1.2). Of those fossils, stromatolites and microbial mats occurring in the 3.49 Ga old Dresser Formation and in the 3.45 Ga old Strelley Pool Formation represent some of the most convincing, best preserved and widely accepted proofs for an about 3.5 Ga old Archaean biosphere (Wacey, 2010; Wacey, 2012; Bontognali *et al.*, 2012; Kranendonk, 2011; Noffke *et al.*, 2013; Sugitani *et al.*, 2015; Duda *et al.*, 2016). Similarly, evidence for Palaeoarchaean microbial activity has been reported from the "twin" craton of Kaapvaal, in southern Africa (Tab. 1.2). Here the oldest microbial fossils occur in the greenstone belt of Barberton, one of the classic location for early Life studies and also the geological setting investigated during this work.

The Pilbara Supergroup and the Barberton area offer undoubtedly the geological record where the early microbial evolution can be retraced most faithfully. However this doesn't imply any ease in such reconstruction. At this stage, in fact, another fundamental challenge emerge as researchers are called to disclose cryptic palaeoenvironments developed under an oxygen depleted and highly reducing atmosphere and in oceans deeply affected by diffusive seafloor hydrothermal systems. Such non-actualistic conditions provided us with peculiar

¹The term greenstone belt, which has a metamorphic-grade connotation, is commonly misused when referred to Eoarchaean volcano-sedimentary successions like the Isua Greenstone Belt or the Nuvvuagittuq Greenstone Belt, as those terrains have undergone amphibolite-grade regional metamorphism and thus do not represent true greenstone belts.

enigmatic rocks characteristic of the early Earth geological history. Within those, Archaean sedimentary cherts, with their incredible preservational potential and CM content, represents the preferential deposits where the early biosphere is investigated.

1.2.2 Origin and biological significance of Archaean cherts

Cherts are deposits composed almost entirely by silica (> 75%) in the form of microcrystalline quartz and represent a recurrent component in the Archaean marine volcanosedimentary successions. On the modern Earth, since the beginning of the Proterozoic, the oceanic silica concentration has been kept extremely low mainly by the activity of organisms constructing Si-skeletons. With no evidence for such biological control, the abundance of chert deposits in the Archaean record is thought to reflect the non-actualistic conditions in which the early Earth environments developed, whereas abiotic quartz precipitation occurred out of a Si-rich seawater (Maliva *et al.*, 2005). However, the factors and processes which controlled cherts formation are still unclear and the object of a longstanding scientific debate.

Archaean cherts are representative of a variety of depositional facies including bedded, stratiform horizons, crosscutting and stratiform veins, dykes and massive layered rocks (Lowe and Knauth, 1977; Lowe and Fisher Worrel, 1999; Van Kranendonk et al., 2003; Hofmann et al., 2007). In reason of such heterogeneity and after the occurrence of textural, mineral and elemental relicts, evidence for pre-existing rocks, cherts are largely considered the result of secondary silicification² on a wide range of lithologies including volcanic and volcaniclastic rocks, terrigenous sediments, mud, silts, chemical deposits such as carbonates or evaporites and biogenic sediments (Lowe and Knauth, 1977; Paris *et al.*, 1985; Lowe and Worrell, 1999; Walsh and Lowe, 1999; Van Kranendonk, 2006; Hofmann and Bolhar, 2007). Mechanisms for primary chert precipitation as a colloidal gel, out of Si-saturated seawater and/or hydrothermal fluids, have been also proposed (Boorn *et al.*, 2007; Ledevin *et al.*, 2014) and may better explain occurrences of pure translucent sedimentary cherts or chert veins, such as the botryoidal quartz-filled veins described in the chapters 2 and 4 of this work.

Different models have been proposed for the genesis of secondary cherts and these vary in terms of source, setting and timing of the silicification process. In many investigations chert deposition has been interpreted to have happened very early in the sediments history, possibly syn-depositionally or during the early diagenesis; this is the case of the fossiliferous

² The process of pervasive replacement of the original rock by Si-rich minerals

Archaean cherts whereas silicification probably occurred prior to compaction resulting into the preservation of the original microbial structures. Other occurrences have resulted instead from a much later alteration of rocks. In general the same deposits could have been interested by multiple processes of silicification occurred at various stages during the rocks history. Similarly, several settings and triggers have been suggested.

Considering the presence of an hot Si-rich Archaean ocean some authors have interpreted the silicification as the result of direct interaction between sediments and low-temperature seawater at the sediment-water interface in the absence of hydrothermal activity (Lowe and Knauth, 1977; Lowe and Worrell, 1999; Tice and Lowe, 2006b). Other models proposed instead serpentinization of the oceanic rocks as the source for silica (Wit *et al.*, 1982) or also the devetrification of volcanic rocks (Paris *et al.*, 1985). However, the formation of chert, especially in the Palaeoarchaean record, has been most commonly associated to the circulation of Si-rich hydrothermal fluids, whereas hydrothermal activity was widely diffused on the early Earth (Wit *et al.*, 1982; Paris *et al.*, 1985; Van Kranendonk, 2006; Hofmann and Bolhar, 2007c; Hofmann and Harris, 2008b; Ledevin *et al.*, 2015). This would have resulted into the silicification at the seafloor due to the mixing between hydrothermal fluids and cooler seawater, but also in the subsurface by fracturing, veining or fluid convection through the sediments column.

Although distinct investigations may support contrasting silicification models even for the very same geologic unit, as illustrated in the following section for the geological settings studied in this work, and the origin and exact timing of Si-precipitation may remain shadowy, cherts represent the most informative deposits for the reconstruction of the early Earth surface processes. Particularly, Palaeoarchaean carbonaceous cherts, which are microcrystalline quartz deposits rich in carbonaceous matter, preserving a wide variety of ancient viable habitats are the key lithology in search for Life and provide evidence for the most ancient microbial remains in the form of putative carbonaceous microfossils.

However although carbonaceous morphologies suggest for a widespread Palaeoarchaean biological organic production, abiotic processes occurring on the early Earth are known to result into carbonaceous morphologies and chemistry reminiscent of life without the actual necessity of biological activity (García-Ruiz *et al.*, 2003; Brasier *et al.*, 2006). It results that detailed investigations on the origin and evolution of carbonaceous matter within the Palaeoarchaean cherts are fundamental to improve our understanding of the early Life evolution.

1.3 Regional geology and fossil record of the Barberton Greenstone Belt

Situated at the eastern boundary of the Kaapvaal Craton, the Barberton Greenstone Belt (BGB) of South Africa and Swaziland (Fig. 1.1) is a succession of volcano-sedimentary rocks termed the Swaziland Supergroup (Viljoen and Viljoen, 1969; Ronde *et al.*, 1994; Lowe and Byerly, 1999) which have experienced regional lower greenschist facies grade metamorphism that reached the amphibolite grade in proximity to the surrounding and intruding granitoid domes (Lowe and Byerly, 1999; Tice *et al.*, 2004). The belt is a NE-SW elongated structure which reaches about 150 km in length and 50 km in maximum width and can be divided into northern and southern domains separated by the major Inyoka Fault system. It consists of almost vertically dipping strata tightly folded into a number of synclines and anticlines which offer a journey through the whole Palaeoarchaean time by a simple N-S walk in the field. The Barberton Greenstone Belt is composed of three major stratigraphic units (Lowe and Byerly, 1999; Hofmann and Bolhar, 2007): (I) the basal ultramafic-volcanic dominated Onverwacht Group; (II) the overlying Fig Tree Group, made mainly of argillaceous shales and volcaniclastic sediments; and (III) the youngest siliciclastic Moodies Group.

Dated between about 3.57 and 3.30 Ga, the Onverwacht Group is the most basal unit of the belt and consists of a series of submarine volcano-sedimentary successions representative of intense extrusive activity alternating with periods of volcanic quiescence. Each sequence consist typically of a basal thick volcanic unit highly silicified at its top, an overlying highly silicified volcaniclastic deposit and finally a minor thickness of capping sedimentary chert often enriched in CM (Lowe and Byerly, 1999; Hofmann and Bolhar, 2007). Silica-filled dykes, vein systems and cavities observed especially at the top the sequences, in the upper magmatic sections and sedimentary cherts, have been interpreted as the result of hydrothermal activity possibly related to the residual energy trapped within and escaping from the cooling underlying ultramafic-rocks (Hofmann and Bolhar, 2007; Hofmann and Harris, 2008; Ledevin et al., 2015). South of the major Inyoka Fault system, the Onverwacht Group has been subdivided into six formations, the basal highly metamorphosed Sandspruit and Theespuit formations, the Komati, Hooggenoeg, Kromberg and Mendon formations (Viljoen and Viljoen, 1969; Ronde et al., 1994; Lowe and Byerly, 1999b). North of the fault, rocks have been grouped in the Weltevreden Formation. Overlying the Onverwacht Group, the 3.26 to 3.23 Ga old Fig Tree is composed of distinctive northern and southern domains (Hofmann, 2005). The northern facies consist mainly of turbiditic greywacke, shale and felsic volcanic rocks representative of deep-marine environments. The southern facies instead formed in a

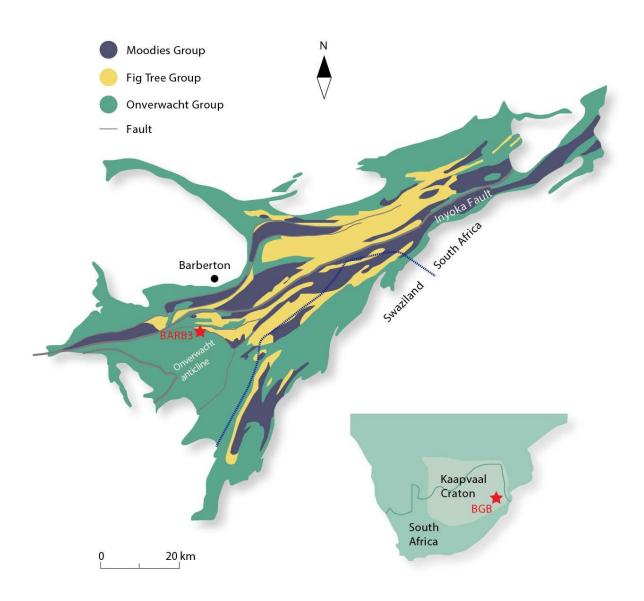


Figure 1.1 - Geological map of the Barberton greenstone belt in South Africa and Swaziland within the Kaapvaal Craton, showing the location of the BARB3 drilling hole (star). After Homann et al. (2015).

shallower setting and include beside shale and greywacke also a variety of coarse siliciclastic sedimentary rocks, minor conglomerates, cherts and jaspilitic banded iron formations. Horizons of impact spherules have also been recognized at the base of both the Fig Tree domains (Lowe *et al.*, 2003; Hofmann *et al.*, 2006). Completing the BGB succession is the youngest Moodies Group which was deposed in a shallow-marine to fluvial environment about 3.22 Ga ago (Hessler and Lowe, 2006). This include thick sandstones, conglomerates, minor shales and banded iron formation.

The BGB represents a classic location to investigate the early record of life. Cherts of the Swaziland Supergroup are rich in sedimentary carbonaceous material which has been interpreted as the remains of microbially produced organic matter (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006c). A wide range of putative microbial features has been reported, including filamentous, coccoidal, spindle-shaped and spheroidal microfossils (Knoll and Barghoorn, 1977; Walsh and Lowe, 1985; Walsh and Lowe, 1999; Walsh, 1992; Javaux *et al.*, 2010; Homann *et al.*, 2016; Kremer and Kaźmierczak, 2017), stromatolite-like structures (Byerly *et al.*, 1986; Walsh and Westall, 2003) and fossilised carbonaceous mats (Walsh and Lowe, 1999; Tice and Lowe, 2004a; Tice and Lowe, 2006c; Noffke *et al.*, 2006; Westall *et al.*, 2011; Westall *et al.*, 2015; Homann *et al.*, 2015). Within this fossil record, microbial mats from the 3.4 Ga sedimentary succession of the Buck Reef Chert (BRC) represent one of the oldest claims for life on Earth (Walsh, 1992; Tice *et al.*, 2011).

1.3.1 The Buck Reef Chert: a cradle for early microbial life

1.3.1.1 Stratigraphy

Located in the Barberton Greenstone Belt along the western limb of the Onverwacht Anticline at the contact between the Hoggenoegg and Kromberg formations the Buck Reef Chert represent one of the few well-preserved, low- grade metamorphic (lower greenschist facies; (Tice *et al.*, 2004) Palaeoarchaean sedimentary units on Earth. Its age is constrained by 3416 ± 3 Ma old zircons (Krüner *et al.*, 1991) from a thin detrital layer at the succession's base and the 3334 ± 5 Ma old Footbridge Chert situated at the top of the Kromberg Formation 1.3 km above the sequence (Byerly *et al.*, 1993; Byerly *et al.*, 1996).

The BRC consists of an unusually thick (up to 400 m) sequence of mainly black-andwhite banded sediments composed almost entirely of microcrystalline quartz (chert) enriched in carbonaceous material and other accessory minerals. Minor silicified banded units are a recurring feature of the Palaeoarchaean volcano-sedimentary successions (de Vries *et al.*, 2010). Three main lithofacies have been recognized in the succession (Fig. 2.1) (Lowe and Worrell, 1999; Tice and Lowe, 2004, 2006a;b):

I. A basal evaporitic facies which includes silicified ripple laminations (Fig. 1.2a) and chert lenses interfingering with underlying silicified volcaniclastic sandstones of the Hoggenoegg Formation. Pseudomorphs after nahcolite, silicareplaced evaporitic crystals and botryoidal quartz-filled cavities (Fig. 1.2b) have been also reported (Lowe and Worrell, 1999; Tice and Lowe, 2004, 2006b). Locally, at the top of the evaporitic and botryoidal chert, a 50-100 cm thick

pseudo-conglomerate consists of banded and evaporitic chert fragments in a quartz and botryoidal quartz matrix (Hofmann and Bolhar, 2007) (Fig. 1.2b);

- II. A platformal facies of black, carbonaceous, and white banded chert. This is characterized especially in the lower part by disrupted or brecciated banded chert units and by the occurrence of megaquartz-filled cavities (Lowe and Worrell, 1999; Tice and Lowe, 2004,2006b);
- III. A basin facies of more compacted and finely laminated ferruginous banded chert. Here bands disruption, brecciation and quartz-filled cavities are rare or absent (Lowe and Worrell, 1999; Tice and Lowe, 2004, 2006b).

A further upper platformal division is found locally on the west limb of the Onverwacht anticline. The succession is finally capped by a thick ultramafic sill which separate the BRC from the ultramafic lapillistone of the overlying Kromberg Formation.

The BRC facies have been interpreted as deposited in a coastal-lagoonal to open marine environment, based on stratigraphic progression from evaporites to homogeneous banded units, which traditionally reflect a transition from shallow to deeper marine conditions (Lowe and Worrell, 1999; Tice and Lowe, 2006b). However, some aspects of the environment, with pivotal implications for the ecosystem reconstruction, remain cryptic, such as the influence of hydrothermal activity on the BRC deposition (Hofmann, 2011).

1.3.1.2 The role of hydrothermalism in the Buck Reef Chert

Hydrothermal activity during BRC deposition has been suggested by de Vries (2004) and de Vries et al.(2006) in relation to syn-depositional normal faulting which according to those authors may have driven the formation of the Buck Ridge volcano-sedimentary complex. On the other hand, Tice and Lowe (2004, 2006a,b) considered the BRC to represent sediments deposited in a non-hydrothermal environment. They pointed at the absence of exhalites, fluid conduits and hot springs and suggested silicification of the deposits trough the interaction with hot marine water supersaturated in amorphous silica directly at the sediment-water interface. Nevertheless, cross-cutting and planar vein networks interpreted as the remains of hydrothermal systems have been reported below the basal chert horizons of the BRC and support active syn-depositional hydrothermal venting at least for the lower part of the succession (Hofmann and Bolhar, 2007). Hofmann and Bolhar (2007) and Hofmann and Harris (2008), based on such structural evidence and geochemical data, provided a model for



Figure 1.2 – Evaporitic section of the BRC outcrop. a) wavy laminated white and translucent chert from the basal BRC evaporitic facies interpreted to represent Paleoarchean ripples formed in coastal-lagoonal environment (Tice and Lowe, 2006b). b) botryoidal quartz-filled cavity or vein at the top of the BRC basal evaporitic facies occurring in the conglomerate (Tice and Lowe, 2006b) or pseudo-conglomerate, chert breccia (Hofmann and Bolhar, 2007) section. Such features recur frequently also in the ripple section and in the overlying platformal facies, they have been interpreted differently depending if hydrothermalism has been supported or not during the BRC deposition.

the development of chert veins, silica alteration zones and the origin of overlying stratified cherts horizons. According to this model convection of Si-saturated seawater, driven by the high regional heat flow caused sediments silicification at the sediment-water interface as the hydrothermal fluids were cooling after mixing with seawater. Such process formed impermeable silicified caps inducing overpressure in the hydrothermal system and eventually hydrothermal brecciation and branching of stratiform veins. Finally, unsilicified carbonaceous sediments would have entered the conduits resulting into carbonaceous veins observed today in the field. Similar processes have been previously proposed in a general model for the silicification of volcanic rocks and the formation of veining systems within the BGB (Paris *et al.*, 1985).

A compelling aspect of the debate is the significance of the botryoidal quartz-filled cavities (Fig. 1.2b) found in both the evaporitic and platformal facies of the BRC. In the non-hydrothermal settings (Tice and Lowe 2004, 2006) they are regarded as dissolution cavities formed in the phreatic zone, in the evaporitic facies, and as fluid escape structures resulting from soft-sediment disruption after storm events, in the platformal facies. In the hydrothermal model (de Vries *et al.*, 2006; de Vries and Touret, 2007; Hofmann and Bolhar, 2007; Hofmann and Harris, 2008) the same structures have been described as the result of veining, brecciation and precipitation of colloform silica after upwelling and pervading silica-rich fluids. However both interpretations rely on the depositional settings supported by the respective authors and the botryoidal quartz-filled cavities haven't been directly investigated yet.

1.3.1.3 Carbonaceous matter and traces of life in the Buck Reef Chert

The BRC has long been appealing for early life researchers, as the succession is rich in sedimentary carbonaceous material, which, as described in the previous chapter, brings implications with concern to possible ancient microbial organic production. In fact, CM from the BRC, similarly to the rest of the BGB, has been suggested to be largely, if not entirely, of biological origin (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006b). This view is supported by morphological evidences of diffuse carbonaceous laminations interpreted as the remains of seafloor microbial communities and by the occurrence of such laminations and other CM-rich textures in cherts deposited during periods of volcanic quiescence, in environmental settings suitable to life (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006b). Isotopic composition of the carbonaceous matter has been also used to invoke

different microbial metabolic pathways and in general the BRC CM has been placed in textural, compositional, depositional and abundance continuity with sedimentary kerogens of the younger Precambrian geological record, implying thus a similar microbial origin (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006b). Furthermore the same investigators (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006b) have precluded possibilities of carbonaceous remobilization or hydrothermal inputs as hydrothermalism during BRC deposition has been excluded.

Previous workers have been focusing mainly on the BRC shallow-platformal facies as in this lithofacies CM is particularly rich, texturally diverse and preserves morphological evidences for a Palaeoarchaean microbially active environment. Here, anastomosing, bifurcating and cohesive carbonaceous-rich laminations have been recognized as wellpreserved microbial mats (Walsh, 1992; Tice and Lowe, 2006b). Tice and Lowe (2004, 2006a,b) and Tice (2009, 2011) provided extensive and detailed investigations on such structures which they classified into three major morphotypes possibly reflecting different populations of mat-constructors. Excluding hydrothermal activity from the BRC, hence from the possible sources for microbial sustenance, those authors evaluated the intact laminations focusing on their exclusive distribution within the platformal facies. Such restriction to estimated depth between 15 and 200 m was regarded as a microbial confinement to the euphotic zone. Accordingly, in spite of the aforementioned morphotypes distinction, all mats were seen as produced by photosynthetic communities, with the BRC δ^{13} C isotopic composition falling between -35‰ and -30‰ (Tice and Lowe, 2006b), consistent with carbon fixation through the Calvin cycle by autotrophic microorganisms.

The view of the BRC mats as the remains of photosynthetic microbial communities largely rely on the environmental constraints proposed. However, as reported above, hydrothermalism has also been supported (de Vries *et al.*, 2006; de Vries and Touret, 2007; Hofmann and Bolhar, 2007; Hofmann and Harris, 2008) so that pathways of CM production and maturation and the trophic identity of microbial communities at the BRC are at the centre of a controversy thus in need of further elucidation.

1.4 This study

Much has been written in recent years concerning the biogenicity dilemma of ancient CM and two principal approaches can be recognized. The first, namely the "list of criteria approach" (Awramik *et al.*, 1983; Buick, 1984), propose a list of positive (bio-affine) and

negative (abio-affine) tests against which CM should be verified to identify possible biogenic rather than abiotic features. The second, the "falsification approach" (Brasier et al., 2002, 2004), suggest a more systematic test against possible abiotic hypotheses; in this way the "falsification approach" appear to be an implementation of the "list of criteria" whereas more abiotic hypotheses are tested. However, as wisely pointed out by Tice and Lowe (2006b), both approaches, at the state of our current knowledge, fail in defining a finite set of criteria to clearly establish the biogenicity of ancient CM and both procedures rather set the stage for an infinite list of possible null hypothesis. On the other hand researchers have noted how many Archaean CM properties such as its structure, composition, depositional and preservational environments and abundance are basically in continuity with the younger Precambrian record (Tice and Lowe, 2006b). At the same time recent increasing evidence for a Palaeoarchaean microbial biosphere have in many cases already opened discussions about ecological behaviour of ancient microbial remains (Tice et al., 2011). In this way much of the CM from the Pilbara Supergroup and Barberton Greenstone Belt, following the Occam's razor principle, appear more reasonably comparable with younger biogenic deposits rather than tested against an infinite set of "null hypothesis".

Following such philosophy in this project investigated CM-rich drill core (BARB3) material from the c. 3.4 Ga old Buck Reef Chert of the Barberton greenstone belt of South Africa, one of the best preserved, less metamorphic Archaean volcano-sedimentary succession on Earth and a classic location for the early Life research. A multiple analytical approach, based on *in situ* complementary techniques, is here used to characterize the BRC shallow-platformal CM within its mineralogical context, from the core down to the atomic scale, to investigate its origin and evolution in the perspective of the BRC depositional environment open debate (Hofmann, 2011)

The aim of this study has been to: (I) recognize evidence of biological activity within the core through the morpho-chemical characterization of potential microbial fossils; (II) investigate the provenance and relationships between CM in the different lithofacies to test theories for CM origin and evolution; (III) search for biosignatures, if any, and techniques for early life detection; (IV) contribute to the Paleoarchean environmental reconstruction. Chapter 2

From the outcrop to the Ångstrom: materials and techniques for the characterization of carbonaceous matter from the BARB3 drill core in its mineralogical context

2.1 Peering into the cradle of life

In May 2012, aiming to improve our understanding of geological and biogeochemical processes on the early Earth through the investigation of extraordinarily well-preserved Palaeoarchaean material, the ICDP-sponsored Barberton drilling project completed piercing at four sites in the Barberton Greenstone Belt obtaining five continuous and relatively unaltered sections through the southern African volcano-sedimentary succession (Arndt *et al.*, 2013). The main targets of the drilling were: (I) sedimentary sequences, with the intent to provide insights into the early Earth surface processes, including modes of sedimentation, geochemical cycles, marine/hydrothermal conditions and the evolution of the early biosphere; (II) ultramafic to felsic volcanic rocks to reconstruct the dynamics and rate of extrusive, crustal and mantel processes.

Responding to the first purpose, a single core, the BARB3 drill core (Hofmann et al., 2013a), was obtained from the ~3.4 Ga old Buck Reef Chert sedimentary unit which, as showed in the previous chapter, represents an excellent location for ancient biological and depositional processes investigation. Focusing on traces of microbial activity and possible early life environments preserved in the BARB3 material, this study is a contribution to the Barberton drilling project early life investigation.

2.1.1 Stratigraphy of the BARB3 core

The BARB3 core consist of a total length of ~899 m drilled at an angle of 45° to the BRC sedimentary plane (Hofmann et al., 2013a). About 200 m of the serpentinized peridotite sill at the base of the Kromberg Formation was first intersected while the majority of the core (618 m) consists of sedimentary carbonaceous and ferruginous banded cherts intruded by two minor sills, mafic and felsic respectively (Fig. 2.1). Based on their textures and degree of compaction, sedimentary cherts, which are estimated to represent an actual stratigraphic section of about 337 meters (618 *sin* 45°), can be divided into a lower, an intermediate and a top division, corresponding to the succession of two main lithofacies along the core. The lower and top sections (I) consist mainly of interspersed ferruginous, carbonaceous and white chert mesobands³ and are both characterized by the occurrence of frequent stratiform

³In reason of their bedded nature on a multiple range of scales and of their iron-rich content, the terms mesobands (centimetre-thick bands) and microbands (millimetre and sub-millimetre thick bands), typically used for Precambrian banded iron formations(Ayres, 1972; Konhauser *et al.*, 2002; Rasmussen *et al.*, 2013), appear particularly suited to the description of the BARB3 chert divisions.

botryoidal quartz-filled veins, granular carbonaceous chert layers and brecciated white chert slabs conferring an overall heterogeneous aspect to the core especially at its base (Fig. 3.1). The intermediate division (II) is largely a banded iron formation (BIF) composed of an alternation of notably more homogenous and compacted mesobands of siderite and white chert characterized by sparse bright-red jasper mesobands and by the reduction and loss of those attributes distinctive of the lower and upper sections including black chert, granular carbonaceous chert and botryoidal quartz-filled veins. The overall BARB3 chert sequence can be readily correlated with the BRC stratigraphy (Fig. 3.1) proposed by Lowe and Fisher Worrell (1999), Lowe and Byerly (2003) and Tice and Lowe (2004), particularly to the so called platformal-basinal-platformal lithofacies succession observed on the west limb of the Onverwacht anticline (Tice and Lowe, 2004), with the main core lithofacies described above corresponding respectively to the BRC shallow-platformal facies (I) and deeper basin facies (II). The basal evaporites of the BRC succession are not represented in the BARB3 core as they were not traversed during the drilling.

2.1.2 Sampling from the BARB3

All the samples analyzed during this investigation derive from the BARB3 core (Fig. 2.1) which at the time of this study was housed at the Department of Geology, University of Johannesburg. The BARB3 drill core was systematically sampled to provide 26 quarter core specimens representative of stratiform chert horizons corresponding to the Buck Reef Chert shallow-water platformal facies and 5 specimens from the deep-water basin facies. Although some preliminary mineralogical data was obtained from the basin samples, this study focus on the upper and lower platformal deposits. Core cutting was performed at the Department of Geology, University of Johannesburg, using an Almonte Automatic Core Cutter. 42 polished petrographic 40 µm thin sections⁴ was prepared for analyses at the thin section preparation lab of the Department of Biological, Geological and Environmental Science (BiGeA), University of Bologna and 20 more sections were produced at the Central Analytical Facility of the Faculty of Science (Spectrum), University of Johannesburg. During

⁴Due to the optical translucent quartz-rich composition of the analyzed material, the in-depth working techniques used during this study, except for transmitted infrared spectroscopy that required a special preparation (see the vibrational spectroscopy section), are not affected by the original section thickness. Considering this, thin sections thicker than the usual 30 μ m were prepared in order to increase the volume of analyzed material and the chances of including possible traces of life.

Buck Reef Chert

BARB3 core

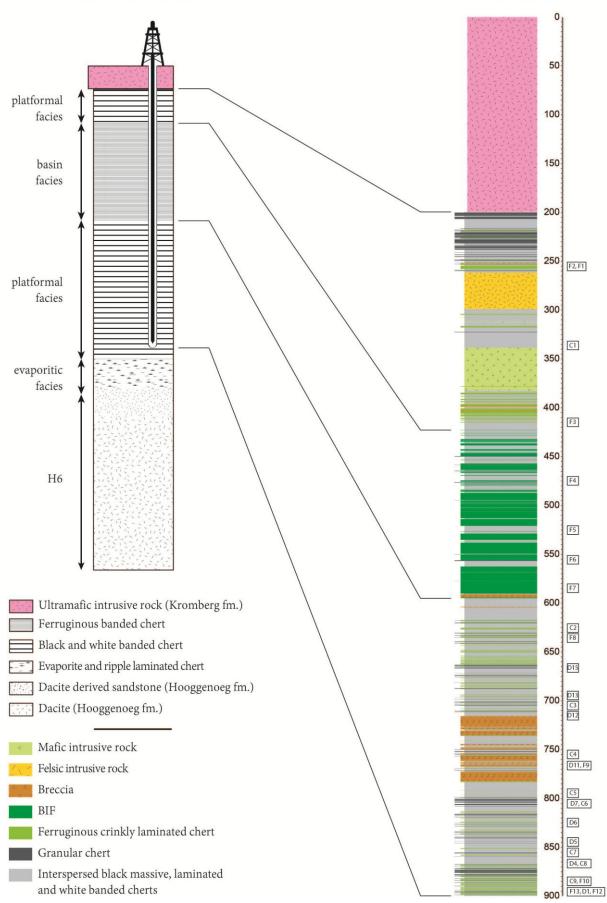


Figure 2.1–Stratigraphic logs of BARB3 core (Hofmann, unpubl.), with sampling vs the Buck Reef Chert.

this study most of the analyses were conducted on such prepared standard polished petrographic thin sections, in the cases where further preparation was needed this will be illustrated as part of the analytical method for which it was required. For details concerning samples provenance along the core, represented facies and employed techniques refer to S1 supplementary material.

2.2 A multiple analytical approach

In the absence of "smoking guns" (Tice and Lowe, 2006b) providing unequivocal evidence for life, investigators of the ancient geological record are called to face the ambiguity between abiotic and biotic signatures. Moreover, biogenicity and syngenicity of possible microbial traces need to be tested within rocks which even when weakly metamorphosed may not easily allow the identification of primary rather than postdepositional features, especially considering that our understanding of depositional processes on the early Earth is still shadowy. Such complications require extreme caution and an investigative approach to be applied at different scales in order to obtain multiple lines of evidences for life (Wacey, 2009). Particularly one should be able to recognize an environment compatible with life from the outcrop down to the micro-scale of the mineralogical context embedding the hypothetical biosignature. An exhaustive approach would than verify evidences of biological morphology, including possible indicators of microbial behaviour, a carbonaceous rich composition in the case of direct microbial remains (including EPS and mat remains) or bio-affine elemental enrichments in the case of indirect biosignatures, and finally metabolic pathways consistent with the reconstructed environment possibly supported by suitable isotopic fractionations (Brasier and Wacey, 2012; Brasier et al., 2015; Wacey et al., 2017).

Similar steps need to be followed when retracing the origin of Palaeoarchaean CM and its possible relation to microbial activity (Oehler and Cady, 2014). The depositional environment needs to be clarified in order to understand which abiotic and biotic pathways may have been possibly responsible for the CM production and the extent of their respective contributions to the rocks carbonaceous content. CM should be also chemically and structurally characterized at different scales within its mineralogical context to provide insights about the nature of its possible original precursor and about the processes of maturation which have led to its actual form. Particularly, by means of several analytical techniques, CM can be investigated at its multiple levels of organization corresponding to its texture, microtexture, structure and nanotexture.

In this work multiple and complementary analytical tools operating at different scales have been applied to the BARB3 drill core material. The investigation has been focused on the BRC shallow-platformal lithofacies and their carbonaceous content. The experimental approach has been carried out following two parallel interdependent lines of investigation: (I) the examination of the depositional and mineral-petrographic context in which the BARB3 CM occur through direct core observations, optical microscopy, Raman spectroscopy, scanning and transmitted electron microscopy; (II) the characterization of the BARB3 CM at its various level of organization through direct core observations for its textures, optical microscopy for the microtextures, infrared and Raman spectroscopy for the carbonaceous structure and high resolution transmitted microscopy for the nanotexture.

The study of the BARB3 material was also supported by observations made directly from the BRC outcrop in the field and some field evidences will be presented in the form of photographic material.

2.2.1 Core survey and optical microscopy

The whole BARB3 chert succession was inspected during the sampling process, however direct observations were focused on the shallow-platformal facies. Observations with the unaided eye and the hand lens took place at the core storage facility, while further inspections were done on hand specimens and with the assistance of a Zeiss Discovery Stereo Microscope, Spectrum facilities. Optical petrography and fabric mapping were performed on polished thin sections using a Zeiss Axioplan Microscope equipped with a Nikon HS DS-Vi1 colour camera at BiGeA and a Zeiss Axioplan 2 Compound Microscope equipped with an AxioCam HR colour CCD camera at Spectrum facilities.

2.2.2 Vibrational spectroscopy

Spectroscopy investigates the interactions between the electromagnetic radiation and matter and it can be classified depending on the energy of the radiation employed and on the type of interaction promoted. In vibrational spectroscopy low-frequency radiations, typically in the infrared or visible spectra, interact with the molecular vibrational modes inducing low-energy quantum transitions. As vibrations happen at specific frequencies depending on the

atomic masses involved, their bonds and spatial arrangement, the detection of such interactions provide insights into the structure of the analyzed substance.

The two most commonly used vibrational spectroscopic techniques are infrared (IR or more commonly FTIR, Fourier Transform Infrared spectroscopy) and Raman spectroscopy. In both of these processes when light interacts with the matter vibrations, exchanges in energy occur and result in a difference between the original and the collected radiation. Such difference can be detect and visualized on a graphic spectrum in the form of peaks appearing at specific frequencies which are diagnostic for the chemical structure of the investigated sample. It follows that IR and Raman spectroscopy can be used for the identification and the structural/chemical characterization of minerals, but also amorphous materials like the organics buried within sediments or other CM. Particularly, for reasons of the energy involved, IR is more sensitive and thus more suited for strongly polarized bonds typical of functional groups such as C-N, C-O, C=O, N-H and O-H, while neutral or weakly polarized bonds composing the molecular frameworks such as C-C, C-H, S-H, C=S, and C=C produce stronger Raman scattering (Olcott Marshall and Marshall, 2015). The two methods thus provide complementary information about the structural characteristic of the investigated substances. During this work Raman and FTIR-microspectroscopy, representing both nondestructive *in situ* techniques have been applied to structurally characterize meta-sedimentary BARB3 CM. However during the IR analytical work several difficulties have been encountered which can be related to the employed experimental method. In reason of such difficulties a proper IR characterization of CM, also due to the limited analytical time available, has not been possible. However believing this technique has a great potential interested researcher are suggested to read the fundamental work of Igisu and collaborators (Igisu et al., 2006, 2009, 2011, 2014) and Preston et al.(2011) but also to the more recent and very interesting studies by Qu et al. (2015, 2017).

2.2.2.1 Raman spectroscopy

During the interaction of visible light with matter discrete amounts of energy can be exchanged between the incoming radiation and the vibrational modes of crystals or molecules composing the irradiated substance. Such transfer may results in an inelastic scattering of light known as Raman scattering (or Raman light), named after the physicist C.V. Raman who first observed and described the phenomenon (Raman, 1928). As the shift in energy between the incoming and scattered radiation reflects the frequencies of specific vibrational modes,

related to specific atomic masses and bonding, detecting and interpreting the Raman light can "[...]enable us to obtain insights into the ultimate structure of the scattering substance." (from C.V. Raman Nobel lecture, 1930). Raman spectroscopy represent a unique technique to investigate vibrational properties of materials and it can be used to characterize the chemical structure of a sample by mean of a low-energy, non-destructive radiation.

In Raman spectroscopy the substance under investigation (solid, liquid or gas) is most commonly irradiated with a laser light having a wavelength ranging between 514 and 785 nm (Andò and Garzanti, 2014). However other radiations, like near-infrared light (NIR-Raman spectroscopy, Schrader et al., 1999), are also employed depending on the specific case necessity. Interacting with the sample a component of the incident laser light can be scattered elastically (Rayleigh effect) and, in a minor portion, inelastically as a result of two type of events, a gain of energy (anti-Stokes Raman scattering) or a loss of energy (Stokes Raman scattering). Those energy transfers results into discrete shifts of the original radiation frequency towards higher (anti-Stokes) or lower (Stokes) frequencies. In Raman spectroscopy, by mean of a CCD collector and specific software, the scattering events can be quantified in terms of their frequencies and counts which can then be plotted as Raman spectra. Here the inelastic scattering is visualized in the form of peaks whose shapes and positions in relation to the original frequency (represented by the Rayleigh line) are diagnostic for peculiar atomic vibrational modes and thus for the sample chemical structure. Particularly a specific Raman-active mode will produce a Stoke and a symmetric anti-Stoke counterpart, however, as the gain in energy by the incoming radiation happen with less probability (low counts), only the Stoke part of the spectra is usually considered. Therefore, by convention, the Stokes shifts are expressed with positive wavenumber values starting from the Rayleigh signal which represent the zero Raman shift. In this way the Raman spectrum pattern gives us insights into the structural characteristics of the investigated sample.

The association of the above described methodology to standard or confocal optical microscopes, namely Raman micro-spectroscopy and Confocal Raman spectroscopy (Dieing *et al.*, 2011), results into an efficient and versatile analytical technique which allows the characterization of materials in-situ at the micron scale. The application of automated stages to such instruments have further improved research opportunities introducing Raman imaging facilities (Salzer and Siesler, 2009). In such technique selected areas of the studied sample are automatically scanned by lines of punctual Raman measurements. From the obtained dataset the operator can than select a specific wavelength to map its intensity through the analyzed area. The result is an image where each pixel, corresponding to each analyzed point, have a

brightness (on a preset colour) reflecting the intensity of the selected wavelength in that specific position of the map. In this way Raman imaging highlight the distribution of specific molecular vibrations and maps can be compared to optical images of the same area. In reason of such possibilities and of the non-destructive energies employed Raman microspectroscopy is now applied to a wide range of research fields including geology.

Raman Spectroscopy in mineral-petrographic investigations

Allowing the characterization of the chemical structure in crystalline materials, Raman spectroscopy finds its first geological application in mineral identification. Common rockforming minerals can be recognized with great precision as their vibrational modes produce diagnostic bands at characteristic wavelengths with specific relative intensities, making this technique an excellent fingerprinting mineralogical-petrographic tool (Fig. 2.2). Furthermore, Raman analyses present some important advantages over other routinely mineralogicalpetrographic techniques. Raman micro-spectroscopy can identify directly observed grains and crystals, with a resolution down to a few microns, independently from their orientation in the sample. Also the method doesn't require any specific preparation and it can be applied to both hand-specimens and normal petrographic thin sections in contrast to SEM-EDX which usually involve some invasive sample preparation. Additionally if electron-beam based measurements provide the bulk elemental content of the analyzed volume through the Raman scattering we can directly discriminate the different occurring mineral phases in the investigated spot. Finally, while SEM-EDX or EMPA are both working at the sample surface, Confocal Raman spectroscopy allows investigation at depth finding its ideal application in mineral inclusion studies (Beran and Libowitzky, 2004; Frezzotti et al., 2012).

A second crucial benefit of Raman spectroscopy is its sensitivity to amorphous materials and non-crystalline molecules, other than just mineral phases, which allows the detailed characterization of carbonaceous materials and other non–crystalline organic or inorganic compounds buried within rocks. By Raman imaging the interrelationships between both crystalline and amorphous phases can thus be explored so that carbonaceous and organic materials are characterized within their mineralogical context. The sensitivity of Raman spectroscopy to amorphous materials finds an important application in the analysis and characterisation of carbonaceous materials from throughout the geological record and the

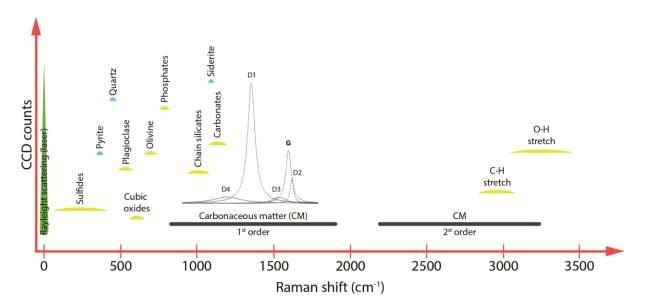


Figure 2.2 – Diagnostic regions for Raman mineral fingerprinting. Diagnostic peaks of specific mineral groups occur within specific wavelength ranges. The first-order Raman spectrum of disordered carbonaceous materials (CM) can result from the combination of up to 5 different bands (D1, D2, D3, D4, G) as shown by a decomposed representative CM spectrum. The G band corresponds to the diagnostic peak of graphite. Weak bands at higher wavenumbers appear in the CM second-order range. Rayleigh scattering results in a zero Raman shift. Modified from Dieing et al. (2010).

technique has been used to investigate the chemical and mineral composition of a variety of fossil assemblages including ancient carbonaceous microfossils (Kudryavtsev *et al.*, 2001; Schopf and Kudryavtsev, 2009) and stromatolites (Allwood *et al.*, 2006).The following section illustrates how the decomposition of Raman spectra by fitting modelling provides a tool to investigate the carbonaceous provenance and to reconstruct the geothermal history of the hosting formation.

Characteristics and evolution of the CM Raman spectrum

The Raman spectrum of carbonaceous material (Fig. 2.2) is composed of two regions: (1) a first-order region (~800-1900 cm⁻¹) which includes frequencies of the CM fundamental vibrations, and (2) a second-order region (~2200-3300 cm⁻¹) with Raman bands corresponding to overtones and combinations of the fundamental modes. It is usually the first-order region which accounts for the features more sensitive to CM structural variations and which, once deconvoluted, is best suited to obtain peak parameters and to characterize the CM disorder (e.g., Marshall et al., 2010).

The evolution of the Raman spectrum of CM is best illustrated by tracing back the carbonaceous maturation from fully-crystalline graphite to completely amorphous CM. In the

first-order region of crystalline graphite only a single line, at ~1580 cm⁻¹, is present. This band, termed the G-band (graphitic), results from the ideal graphitic lattice E_{2g} -symmetry and it is attributed to the in-plane bond-stretching at all of the $sp^2 C$ sites (Ferrari & Robertson, 2000). With increasing in-plane defects due to heteroatoms or in micro-crystalline graphite (Wang et al., 1990), an A_{1g} breathing mode of sp² C within six-fold aromatic rings becomes active and give rise to two D (disordered) bands, respectively the D1 at \sim 1350 cm⁻¹ and D2 at ~1620 cm⁻¹. Additional first-order bands appear with increasing disorder at ~1500 cm⁻¹ (D3) and ~1080-1250 cm⁻¹ (D4). Further disorder in the carbonaceous structure towards almost completely amorphous CM, such as in extremely low-grade metamorphic rocks, results in the loss of the G peak. In this case, the latter may become replaced completely by the D2 signal and a general broadening of the disordered components will be observed with D1 decreasing in intensity and forming a unique broad band together with D4 and D3 (Ferrari and Robertson, 2000; Kouketsu et al., 2014). In such low-metamorphic CM before the G band in sensu stricto (E_{2g}-symmetry) is completely lost, G and D2 both occur combining in a very narrow peak in which the two individual bands greatly overlap resulting in a difficult spectral interpretation. In such poorly ordered CM this narrow peak is named G_L, where "L" stands for Low-temperature or Low-metamorphic (Kouketsu et al., 2014), and correspond to the sum of a prevailing D2 and a decreasing G (s.s.) down to a complete loss of G and a D2 band only.

It follows that the Raman spectrum of CM can be deconvoluted by model fitting from two to five curves and using different functions (Gaussian and Lorentzian being the most frequently used) depending on the level of crystallinity of the analyzed CM (Ferrari and Robertson, 2000; Sadezky *et al.*, 2005; Lünsdorf *et al.*, 2014; Kouketsu *et al.*, 2014). The deconvolution process results in peak parameters, such as peak width, intensity and integrated area, or ratios between those, that can then be used to assess the degree of CM disorder and heterogeneity, and to obtain a true Raman geothermometer (Beyssac *et al.*, 2002; Beyssac *et al.*, 2003; Marshall *et al.*, 2012; Sforna *et al.*, 2014; Kouketsu *et al.*, 2014; see legend in S2).

Analytical settings

Confocal Raman spectroscopy on polished petrographic thin sections was carried out at the Assore Raman Lab, housed in the Department of Geology, University of Johannesburg, using a WITec alpha300-R Confocal Laser Raman microscope equipped with an automated sample stage for micro-Raman mapping. Measurements were obtained at room temperature using a 532 nm wavelength of a frequency-doubled solid-state YAG laser source. All spectra

were collected in the Stokes Raman shift up to 3800 cm⁻¹ using a 600 lines/mm grating and a Peltier-cooled EMCCD sensor for signal detection. Before each experimental session the spectrometer was calibrated with a silicon chip standard. For identification and spatial characterization of minerals punctual and imaging data were collected using 20X, 50X, 100X objectives (N.A. = 0.40; 0.55; 0.90) and a maximum laser power, before the objective, of 3mW, in order to prevent CM thermal alteration. A detailed Raman investigation on different carbonaceous types, identified after optical microscopy, was performed on six petrographic thin sections (D11A, C3A, D1, C9E, C2C, D4A) representative of the main lithofacies described in this work. For each section two different CM microtextures have been selected and each section analysed by means of at least 25 total punctual spectra to produce a statistically significant dataset (Aoya et al., 2010). Measurements on carbonaceous material were collected by focusing the laser beam through a 50X (N.A. = 0.55) objective for 240 s at a power of 3mW. Acquisitions were taken on focal planes selected at more than 3 µm depth into the thin sections excluding possible surface contaminants and eliminating the alteration of the original carbonaceous structure by polishing (Beyssac et al., 2002). Although it has been showed that Raman map-based analyses provide better estimation of the CM average spectra (Sforna et al., 2014), the punctual approach has been preferred during this study for the following reasons: i) a number of 25 spectra is sufficient to explore the within-sample (thin section) CM structural variability (Aoya et al., 2010); ii) the study here focused on the heterogeneity between CM microtextures rather than between facies (Sforna et al., 2014). The punctual analyses in this way are much more accurate to analyze morphological features a few tens of micron in size excluding contamination from adjacent carbonaceous structures and by the diffuse CM particles, furthermore analyzed microstructures were often to small in size when compared to the beam size thus the map-based analyses were pointless; iii) if is true that mapping provide a very large dataset it is also true that this require an extremely long total acquisition time even for very low counts on the single collected spots. On the other hand, the punctual approach allowed to increase the acquisition time and thus the counts providing much better resolved spectra allowing a much more confident fitting and thus increasing the accuracy of extracted parameters and ratio for a much lower total acquisition time, the saved time can be instead used to increase the number of the analyzed structures.

Each recorded spectra was processed using the graphing and data analyses software Origin Lab 8.5 for baseline subtraction, peak identification and curve fitting in the Raman first-order region. For spectral decomposition we applied two different fitting models, a two Voigt curves fitting protocol (D1 and G bands) and a Sadezky (Sadezky *et al.*, 2005) protocol using a combination of four Lorentzian (G, D1, D2, D4 bands) and a Gaussian curve (D3). Parameters and ratios were thus calculated and analyzed to evaluate CM structural order, estimate its syngenicity and assess heterogeneity within and between-samples.

2.2.3 Electron microscopy

In electron microscopy a high-energy, low-wavelength, accelerated electrons beam interacts with matter. Some of those interactions results into scattered or transmitted electrons which can be collected to form an image of the analysed material. As the electrons beam wavelength is many orders of magnitude shorter than that of visible light it is possible to produce images with a resolution power several order greater than what can be obtained in standard optical microscopy, allowing the characterization of details down to the atomic scale. Furthermore, depending on the emission investigated, electron microscopy can be used to provide insights into the elemental composition, the internal structure and crystallinity of the analyzed sample(Watt, 1997).

In this work three electrons beam based microscopic analyses, electron microprobe, scanning and transmitted electron microscopy, have been applied to the BARB3 chert material. Such techniques have been commonly used on the ancient geological record mainly with the purpose to characterize thin section mineralogy and their microfossils and carbonaceous content (Wacey, 2009; Wacey *et al.*, 2017). However, compared to vibrational spectroscopy, electron microscopic methods are more demanding as they work with solids only and, in most of the cases, require a more invasive sample preparation. Moreover, as mentioned above, they make use of an electron beam which is a high energy, destructive, radiation, especially problematic with concern to amorphous CM, whom structure can be easily altered (Gautam *et al.*, 2005). For this reasons electron beam based analyses should be performed only after the less-destructive *in-situ* vibrational spectroscopic techniques and applied being aware that primary signatures, especially carbonaceous structures, could be altered permanently.

2.2.3.1 SEM

In scanning electron microscopy a finely focused electron beam is scanned across the surface of an investigated bulk material, the resulting backscattered and secondary electrons are thus collected to produce an image of the analyzed specimen. Specific further equipments

can be used to detect X-radiations, cathodoluminescence and other phenomena in order to gain a chemical and elemental distribution information from the investigated sample (Watt, 1997). It results that *in-situ* topographic and elemental images of the sample surface can be provided having a resolution down to a few microns or even a few nanometres depending on the instrumental capabilities. In ancient life studies SEM associated to energy dispersive Xray spectrometry (or EDS, which allow a qualitative and semi-quantitative elemental detection within the analyzed volume) has been commonly used as a minero-petrographic tool to investigate the mineralogical context in which possible microbial traces are buried. SEM has been also on HF acid etched silica-rich samples to investigate topographic details of microfossils relieves (Javaux et al., 2004; Wacey, 2009; Agić et al., 2015), however this preparation can easily introduce contamination or alter primary textures and structures. Other thanlimited to the sample surface, with CM and microfossils normally occurring embedded by minerals within the thin sections, another disadvantage of SEM is that, working in a vacuum chamber, the analyzed sample needs to be conductive and thus usually require, especially in the case of highly silicified materials, carbon or gold coating before measurements can be performed. This type of preparation, which in case of carbon coating can contaminate the original CM composition, can be avoided using an environmental SEM (ESEM). In this instrument the sample chamber is kept at a low vacuum allowing the sample surface charging to be suppressed with no need of coating (Reed, 2005).

In this work SEM has been used largely for mineral-petrographic characterization of carbon-rich facies. Further ESEM has been used to map thin sections selected for TEM analyses.

Analytical settings

A selected suite of polished thin section were carbon coated prior to analyses under electrons beam excitation. To preserve them in case of further spectroscopic investigation each section has been only half coated. SEM and EMPA analyses on such prepared material were carried out at Spectrum facilities. Half-coated thin sections were analyzed with a Tescan Vega 3 scanning electron microscope (SEM) coupled with an electron back-scattering detector and an energy dispersive spectrometer (EDS) for elemental mapping and semi-quantitative elemental analyses. The operating conditions were 10 to 14 keV accelerating voltage for imaging and 15 to 17 keV for elemental mapping.

2.2.3.2 TEM and HRTEM coupled to focused ion beam milling

In transmitted electron microscopy the image is produced after transmitted electrons once the beam has passed through an ultra-thin sample. Objects can be magnified up to 10^6 times and resolved down to about 0.1 nm, moreover, as for SEM, other induced phenomena can be exploited to perform elemental and crystallographic microanalyses (Watt, 1997; Egerton, 2005). X-rays can be detected to provide qualitative compositional information in the TEM scanning mode (STEM), furthermore in high resolution transmission electron microscopy (HRTEM), by means of phase contrast imaging, it is possible to produce images of materials at the Ångstrom scale to characterise their crystallinity at the atomic level using magnifications up to 50 million times (Wacey et al., 2017). However, to obtain in-situ data with such a high definition and resolution, an invasive and destructive preparation is required to produce samples having thicknesses in the range between 10 nm to 1 µm which can be traversed by an electrons beam. To realize ultra-thin samples, or at least to thin down some sample areas, preparation include some steps of mechanical thinning followed by lessdestructive more precise chemical, electrochemical or ion-beam thinning (Egerton, 2005). Of those latter methods focused ion beam (FIB) milling can be used directly on standard petrographic thin sections to extract ultra-thin foils for TEM and HRTEM analyses(Heaney et al., 2015). In FIB milling a focused beam of gallium ions is used to bombard the sample and remove material at the atomic scale through a sputtering process (Egerton, 2005; Heaney et al., 2015). Such technique is normally combined to SEM facilities allowing nano-scale cutting precision which can be planned and controlled *in-situ* at specific locations of the thin section through the electrons beam SEM imaging.

Although FIB sample preparation is an invasive and time consuming technique, FIB-TEM and HRTEM analyses represent important means of characterization of ancient geological materials as they provide *in-situ* chemical and structural insights at the atomic scale. FIB-TEM (but also FIB-SEM; Westall et al., 2006), have been frequently used to investigate chemically and structurally ancient microfossils previously detected in standard petrographic thin sections(Kempe *et al.*, 2005; Moczydłowska and Willman, 2009; Wacey *et al.*, 2012; Foucher and Westall, 2012). Furthermore the application of HRTEM analyses bears a great value in CM investigation supplying unique *in-situ* structural information which are complementary to vibrational spectroscopic results. Particularly HRTEM analyses allow the investigation of the CM nanotexture (or nanostructure) which represent the mutual organization in space of its constitutive nanometric polyaromatic C-rich sheets forming the carbonaceous lattice. In HRTEM imaging the profiles of individual polyaromatic planes are visualized as dark fringes and various parameters can be measured including their length, curvature, tortuosity and the inter-layer distance in the basic structural units (BSU) (Olcott Marshall *et al.*, 2014; Apicella *et al.*, 2015; Deldicque *et al.*, 2016). As the carbonaceous nanotexture and lattice characteristics are dependent on the maturational process of the original carbonaceous precursor and its nature, HRTEM represent an important tool in ancient CM studies. A further advantage of CM high resolution studies is the possibility to discriminate minerals in the form of nanoparticles associated to the carbonaceous lattice as those could give insights concerning the original rock protolith and depositional conditions(Rasmussen *et al.*, 2017) or into possible metabolic pathways exploited by microbial communities now represented in the form of carbonaceous remains (Westall *et al.*, 2011).

In this work FIB-TEM and HRTEM microscopy has been used to characterize carbonaceous rich structures for which an hypothetical biological origin has been hypothesised after previous observations through core, optical and vibrational spectroscopic techniques. The process of FIB-TEM sample preparation is illustrated in Fig. 2.3.

FIB preparation of TEM lamellae

Two standard petrographic thin sections, obtained from the BARB3 shallow-platformal ferruginous laminated chert and granular chert (see chapter 4), have been selected for FIB foils extraction. Thin sections have been accurately mapped through optical and ESEM imaging to allow the location of the exact area of interest at the FIB. Optical mapping was performed using the Zeiss Axioplan Microscope equipped with a Nikon HS DS-Vi1 colour camera at BiGeA, while ESEM imaging was carried out at the Centro Interdipardimentale Grandi Strumenti (CIGS) of the University of Modena and Reggio Emilia, Modena, using a Quanta-200 ESEM microscope operating at low-vacuum (≤ 20 Torr) with no need of conductive sample coating. The extraction of six ultra-thin (less than 100 nm to allow also HR analyses)foils bearing carbonaceous structures of interest was performed at the FIB facilities of the Istituto Nazionale di Ricerca Metrologica (INRiM) of Turin, in collaboration with Dr. Enrico Emanuele. Thin sections were first coated with about 10 nm of gold, than ion cutting was achieved using a Quanta 3D DualBeam microscope equipped with a SEM Field Emission Gun (SEM-FEG), operating between 200V and 30kV with a resolution up to 1.5nm, and a Gallium FIB with a resolution up to 7 nm at 30kV.After trenches milling and foils ion

thinning the lamellae where lifted-up from the thin sections and placed on a copper made TEM grid through nanomanipulation. For a review of the FIB foils extraction from thin sections for TEM analyses refer to Wirth (2009).

Analytical settings for TEM and HRTEM analyses

TEM and HRTEM analyses on the six ultra-thin foils were carried out at the Institute for Microelectronics and Microsystems (IMM) of the CNR of Italy in Bologna, in collaboration with Dr. Andrea Parisini. TEM data were obtained using a FEI Tecnai F20 ST transmission electron microscope operating at 200 kV equipped with a Gatan MSC794 CCD camera an EDAX EDS PV9761 SUTW for X-rays EDS spectrometry and a Fischione HAADF detector for STEM. For HRTEM analyses a lower voltage (180 kV) was used to avoid the induction of CM organization by the electron beam energy (Gautam *et al.*, 2005). Measurements where acquired in STEM mode and HR and lamellae were observed before and after short cycles (up to 30 sec) of cleaning with a Fischione 1020 Plasma Cleaner to remove contamination.

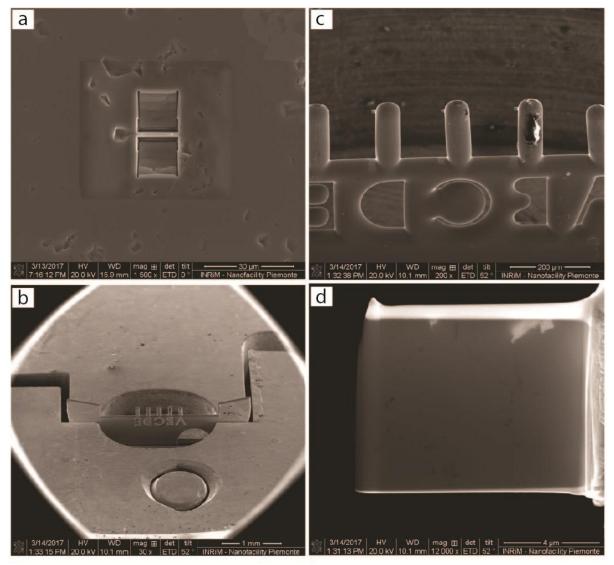


Figure 2.3 – a)SEM imaging at the FIB facility on a gold coated thin section after the first step of ion milling has been completed. Tranches have been cut around a strip which represent the top of the FIB foil which is going to be later thinned, extracted and positioned on the copper grid. (b) for TEM observation. c) A magnification on the copper grid where it's possible to observe tiny lamellae which has been extracted from thin sections and positioned on the comb-like structure of the grid for TEM analyses. TEM-FIB foils have a bigger dimension in the order of a few micrometer and a thickness of ≤ 100 nm (d).

Chapter 3

Characterization of the BARB3 carbonaceous-rich

shallow-platformal lithofacies

3.1 Overview of the BARB3 core lithofacies

With the exclusion of two minor intrusions, 618 m of the BARB3 core consists of sedimentary banded cherts representative of the platformal-basinal-platformal succession observed along the western limb of the Onverwacht anticline in the BGB (Fig. 1.1, Fig. 2.1; Tice and Lowe, 2004). Although this work focuses on the shallow-platformal facies and their carbonaceous content (results summarized at the end of the chapter in Tab. 3.1), a brief description of the overall BARB3 cherts is here provided. The shallow-platformal BRC lithofacies makes up the majority of the BARB-3 core stratigraphy (Fig. 3.1a,b,d). It consists mainly of intercalated mesobands of greenish-grey crinkly laminated ferruginous chert, with common carbonaceous grains and mat-like laminations, and white bedded chert. Along the greenish-grey and white banded layers, that represent the core equivalent of the black-andwhite banded chert observed in outcrop, sparse black carbonaceous facies occur in the form of black massive and black laminated bands. Both the upper and lower units of the platformal facies are characterized by frequent, centimetre-thick, stratiform veins and cavities filled by a lower granular carbonaceous chert and an upper colloform (botryoidal) quartz precipitate. Such structures, which can be used as geopetal indicators, are often associated with adjacent white chert bands being locally fractured. Chert breccia intervals occur especially in the lower facies. In the upper section between 300 and 340 m of the core depth, banded chert deposits have been fractured and veined after lithification, most probably as a consequence of a younger intruding sill (Fig. 3.1). The lower shallow-platformal lithofacies is further characterized by a general higher porosity filled with chert or quartz and heterogeneity at the base of the core that decreases going upwards in the section.

The intermediate BARB3 deep-water division is characterized by a banded iron formation composed by alternating homogenous and more compacted mesobands of ferruginous (concentration of siderite > quartz) and white banded chert (Fig. 3.1c). In the deep water deposits, the ferruginous chert is microbanded and although CM is present, it doesn't occur in the abundance observed for the platformal lithofacies and neither in microtextures clearly suggesting a microbial origin. Compared to the shallow facies, the BIF lacks evidence of botryoidal quartz filled cavities associated with granular carbonaceous chert and also black carbonaceous bands. A distinctive feature of the BIF is the presence of sparse bright-red jasper mesobands (Fig. 3.1c) characterized by a hematite rich and carbonate poor chert composition, and paucity in CM. Jasper bands along the core consistently occur and grade into the siderite rich deposits.



Figure 3.1 – BARB3 core samples from the BRC lower shallow-platformal facies (a,b), deep-basin facies (c) and shallow-water upper unit (d). a) Sample C8 (depth along the core, 865.76-865.63 m) includes a lower massive black chert (mbc) and an overlying greenish-grey crinkly laminated chert (clc). b) Sample C7 (857.19-865.06 m) is representative of a stratiform botryoidal vein (sbv) filled by a a 4 cm thick layer of black granular chert (gc) which is overlying a very thin band of crinkly laminated chert. The top and the bottom of the core sample is composed of white bedded chert (wc) bands. c) Sample F5 (538.30-538.08 m) is part of the deep-water BIF formed by white banded chert (wc) and siderite bands (sd) with sparse jasper mesobands (in red, jsp). d) Sample F2 (256.29-256.10 m) belongs to the upper shallow-platformal section and include again bands of greenish-grey crinkly laminated ferruginous chert and white bedded chert mesobands.

3.2 CM-rich BARB3 shallow-platformal lithofacies

3.2.1 Crinkly laminated chert

Crinkly laminated chert (clc) facies consist of mesobands that range from a few centimetres up to decimetres in thickness⁵. They are characterized by a finely planar laminated texture resulting from the alternation of the following two structural components (Fig. 3.2): (I) discrete, typically greenish-grey, siderite-rich microbands (~1 mm-thick); and (II) interlayered dark black thin (below the mm scale) CM-rich crinkly laminations. Although the facies is usually characterized by a greenish-grey hue it also occurs in darker shades of grey or in a dull yellow colour, reflecting a lower siderite abundance and more frequent CM grains in the first case, and a higher siderite and lower CM content in the second, as observed in thin sections. Pale to white bands, where the crinkly laminated texture is barely recognizable, also occur usually in association with cavities filled with a botryoidal quartz precipitate. In the latter case, the crinkly laminated cherts are characterized by such a low siderite and CM content that they resemble the white bedded cherts facies (Fig. 3.3b).

Fenestrae-like cavities exist together with larger quartz-filled stratiform veins, generally a few mm thick, that can pinch out laterally or extend evenly throughout the whole core diameter appearing to continue as true sedimentary layers (Fig. 3.3a,b). In larger fenestraelike cavities and stratiform veins the infill turns from white at the margins to a dusky- or greyish-blue in the centre reflecting a symmetrical transition from microcrystalline quartz along the edges, to megaquartz in the cavity core (see also granular carbonaceous chert, Fig. 3.15 and Fig. 3.17a). Such transition is characterized by a botryoidal or colloform banding observable directly at the core hand-samples extending from the margin of the cavities towards their interior. Fenestrae-like cavities usually occur at the interface between individual microbands that appear to be plastically banded or may show a local reduction in thickness however, in each case maintaining their lateral continuity (Fig. 3.3a). Microbands in the immediate surroundings of botryoidal quartz filled cavities show local patterns of higher degrees of silicification as observed directly at the core (Fig. 3.3a,b) or in thin section (Fig. 3.8a,b). Individual or groups of microbands characterized by higher porosity and by the occurrence of numerous quartz-filled cavities have been also observed bearing a granular texture consisting of dark grey sandy material (Fig. 3.3a and Fig. 3.8a,b,c). In this case the

⁵ The thickest crinkly laminated chert band observed during this study, not being interrupted substantially by other intercalated facies, is about 35 cm thick. More usually this facies is observed having a thickness averaging around 5 cm.

banding is frequently disrupted and fragmented so that the lateral continuity of individual microbands is difficult to trace. Microbanded deposits have also been affected by the loss of the original depositional continuity as revealed by pressure-dissolution structures. Furthermore, the crinkly laminated facies can be locally faulted or crosscut by carbonate, quartz or botryoidal-quartz filled thin veinlets at various angles with respect to the sedimentary plane (Fig. 3.3a).

3.2.1.1 Microfacies description

In the greenish-grey crinkly laminated chert, microbands (I, Fig. 3.2) consist of translucent, predominantly finely grained (~10-50 µm), rhombic siderite crystals (Fig. 3.4a,b,c,d). These crystals can be found scattered or forming more or less compacted aggregates, up to 1 mm in size, but more commonly about 250 µm, within a microcrystalline quartz matrix. Siderite crystals are typically subhedral to euhedral showing irregular etched margins and frequent chert inclusions, indicating that siderite precipitated probably syndepositionally with the silicification process (Fig. 3.5a). Zonations are common and reflect different relative abundances of Mg, Mn and Ca in the siderite content, with magnesium being the principal iron-substituting element, as indicated by SEM-EDS studies. They may provide information about element mobilization and redox conditions during the growth of the crystal. Individual siderite rhombs larger than 50 µm are usually shattered or composed of smaller euhedral or subhedral crystals. Finely disseminated siderite is scattered within the chert matrix and often concentrated in large ghost rhombs (Fig. 3.5b) now replaced by silica, suggesting that FeCO₃ (or maybe other carbonates) was initially more abundant in this facies. In some cases the iron carbonates bear inclusions of anhedral pyrite suggesting a very early origin for some sulphides (Fig. 3.5c).

Optically opaque material, identified as disordered carbonaceous matter from the typical first- and second-order Raman bands (Fig. 2.2), is found in the form of sub-micron sized particles which occur as diffuse dark domains or concentrated into discrete micron-sized structures including laminae and grains. Laminae (Fig. 3.4a,b,d) are CM enrichments with a thickness of a few microns (usually less than 10 μ m), which, although often disrupted at the micron scale, generally continue laterally across the samples. They are characterized by a wavy-crinkly habit, which gives rise to a slight relief of a few microns in amplitude. Individual laminae occur in the ferruginous microbands gently draping carbonaceous grains, siderite grains and also composite grains made of both CM and siderite (Fig. 3.4b). They are

also arranged into vertical multi-layered lamina-sets, which in core samples appear as the black laminations (II, Fig. 3.2b, 3.4e) defining the crinkly microbanded texture⁶. As indicated by Raman imaging (Fig. 3.4e, inset), these structures consist of laterally continuous CM-rich laminae divided by chert layers that are usually a few microns thick, equating to a total thickness between \sim 50 and 100 μ m. In the lamina-set, contrary to the ferruginous microbands, siderite and CM-grains are scarce or absent (Fig. 3.4e, inset). Lamina-sets bend plastically into wavy morphologies. Here, ductility and cohesiveness of the original carbonaceous material is evident, as laminae produce loosely attached folded-over structures and show anastomosing behaviour (Fig. 3.4e). Discrete carbonaceous material occurs also in the form of equant, irregular simple fluffy carbonaceous grains, up to about 250 µm in size, scattered within the siderite-bearing microbands (Fig. 3.4c). Other than being scattered in the chert matrix or forming rhomb-shaped aggregates, siderite is in general closely associated with both the individual laminae and CM grains as mineral growth and as a partial replacement of the CM-rich structures. This is evident in the form of siderite crystals being locally aligned along individual laminae (Fig. 3.4d) or forming spherical aggregates or ring structures around CM grains (Fig. 3.5d). Microbands rich in CM-siderite grains have a less homogeneous, more granular texture (Fig. 3.3a).

Another, distinct CM microtexture occurs within the post-depositional cross-cutting quartz veinlets and exist through all the chert facies including the crinkly laminated chert. Such CM is very dense and highly reflective under optical microscopy, while SEM analysis can clearly distinguish the CM as forming dense black blobs in backscattered electron images (Fig. 3.6a,b). At the base of the BARB3 core in a sample of very dark carbonaceous rich, poorly preserved, crinkly laminated ferruginous chert (sample D1), a similar dense CM is observed out of the cross-cutting veins, scattered within the ferruginous microbands in the form of smooth spheroids and blobs of various sizes (up to 50 µm) and shapes (Fig. 3.5c,d) and are characterized by an external rim of compact quartz grains coarser with respect to the immediately surrounding microcrystalline matrix. This material that occurs both in veinlets and within sample D1 displays a microtexture that suggests derivation from a carbonaceous fluid phase.

Other than quartz, siderite and CM, mineral phases in the crinkly laminated chert include frequently scattered Fe-, Co-, Ni-, Cu-, Zn and As-sulphides in the form of euhedral

⁶ Although crinkly laminated chert is always composed of discrete ferruginous microbands and interlayered CMrich laminations, it has to be noted that the CM lamination does not always consist of well preserved mat-like lamina-sets but occurs also as unstructured laminar CM enrichments or even in some cases as CM-rich stylolites.

and subhedral crystals. Pyrite, often bearing different proportions of other transitional metals (Co, Ni, Cu, Zn) and arsenic, is the main sulphide and has been recognized also in pseudomorphs after rhomb-shaped crystals (Fig. 3.7a), probably former carbonates. Small pyrite particles, commonly less than ~50 micron and often enriched in Ni, occur in different ferruginous samples scattered or organized in clusters (Fig. 3.7b) typically not larger than a few hundreds of microns. Other accessory minerals include sparse chamosite (Fig. 3.7c), a common occurrence in iron rich deposits that have been metamorphosed to a greenschist-grade and represent a secondary intergrowth and replacement phase after siderite grains or occur finely dispersed in the chert matrix. Calcite is rarely observed forming cross-cutting veinlets and as a later cement (Fig. 3.7d).

As observed along the core (Fig. 3.8a), crinkly laminated bands showing a more granular texture are characterized by intra-granular spaces filled by white chert rather than siderite, they are closely associated with quartz filled cavities and show a partially disrupted microbanded structure. In thin section, the granular material is composed of a mixture of dark CM-siderite grains (Fig. 3.8b), reminiscent of a peloidal texture, and more rarely rip-up, rolled-over fragments of carbonaceous laminae are also overgrown by iron carbonates (Fig. 3.8c). Microbands having such granular texture are also characterized by silica spherulitic precipitation around the CM-siderite grains enriched in a rim of carbonaceous particles (Fig. 3.8d,e). Poorly sorted granular material of similar composition has been observed in lenses that occur as plastic intrusions within the crinkly laminated chert (Fig. 3.3c, 3.8f,g). Finally, microbands bands of ferruginous chert have also been found disrupted after abundant secondary large rhombs, probably originally diagenetic carbonates, that have now been replaced by silica.

3.2.1.2 Interpretation

Abundant carbonaceous laminations occur within the crinkly laminated ferruginous chert and consist of individual or multilayered laminae that in the sediments retain morphologies indicative of an originally plastic and cohesive behaviour. Features including roll-up, folded structures and anastomosing laminae opening around chert lenses are consistent with fossil and modern benthic microbial mats interacting with pervasive fluids or very gentle eroding currents in low energy aquatic environments (Eriksson, 2007; Walsh, 2010; Tice et al., 2011). The preservation of the features described above and the close association of equant carbonaceous grains, advocate for an original carbonaceous laminar

structure rather than representing compression during burial and sediment compaction. The overall morphological features and the characteristic draping of carbonaceous grains strongly support the identification of the BARB3 carbonaceous laminations as microbial mats previously proposed by Tice (2009) and Tice and Lowe (2004, 2006) to represent photosynthetic microbial communities dominating the lower part of the BRC shallow-platformal facies. This suggests that CM simple grains may as well represent microbial remains. In fact, fluffy, irregular, more or less compacted CM-rich grains found in the crinkly laminated chert, as well as in the laminated black BARB3 facies described below, in the BRC outcrop material, closely resemble clotted amorphous CM-rich organic debris documented from many Palaeoarchaean sedimentary cherts and chert veins and from younger sediments where microbial activity is inferred (Ueno et al., 2004; Kiyokawa et al., 2006; Hofmann et al., 2013b; Sugitani et al., 2015). For instance the carbonaceous clotted textures observed in the celebrated fossiliferous Early Devonian cherts of Rhynie and Windyfield in Scotland that represent mainly microbial remains (Fayers and Trewin, 2003; Trewin et al., 2003) bear a close resemblance to the grains of CM documented herein.

A biological origin for diagenetic siderite in Precambrian iron formations has been proposed (Köhler et al., 2013). Carbonaceous grains in the crinkly facies are overgrowth by diagenetic siderite. Siderite beds are known to occur in lacustrine and marine deposits where the mineral is a common diagenetic phase after carbonaceous remnants and iron carbonate can be triggered by exhalative systems or dissolution of less stable carbonates (Bahrig, 1994; Choi et al., 2003; Ohmoto et al., 2004). In Palaeoarchaean deposits the diagenetic growth of siderite on CM cannot imply its microbial origin as CM can, especially in hydrothermal conditions, be generated abiotically (Brasier et al., 2005b; Maurette et al., 2006; Hofmann, 2011). The occurrence of finely disseminated and etched euhedral siderite grains, now partially replaced by chert and the abundance of large quartz pseudomorphs after rhombs, suggest that carbonates were originally more abundant in the core. This provides support for siderite to have represented an early diagenetic phase that possibly occurred soon after CM rich protolith deposition and earlier or syngenetically with respect to the silicification of sediments. Insights about the origin and significance of siderite in the crinkly laminated facies and the reconstruction of the original carbonaceous rich protolith however, requires further investigations.

Despite the nature of the crinkly laminated facies, the protolith is still unclear. The excellent preservational state of the BARB3 carbonaceous mats and their cyclic development into thick anastomosing multilayered structures, detailed by Raman imaging techniques,

suggest that the original sedimentary microfabric is still preserved within the BARB3 laminated ferruginous chert and that CM simple grains and laminae are primary. Particularly the alternation of (I) siderite-rich microbands, where frequent CM equant grains occur together with individual carbonaceous laminae, to thin carbonaceous layers (II) composed almost exclusively of multilayered carbonaceous mats appear to reflect an original Palaeoarchaean intermittent low-rate sedimentation. In such a depositional context well developed multilayered epibenthic carbonaceous mats would have been able to grow during a depositional hiatus, while a higher depositional rate would have prevented such microbial proliferation. Individual laminae within the microbands thus could have represented microbial "survival" modes during high sedimentation rates or a later development of endobenthic microbial mats (Noffke, 2010). This cyclic sequence represented by sedimentary bedding development and the successive re-establishment of microbial mats is consistent with planar stromatolite growth found in various aquatic depositional settings including, deep water microbially active methane seepage (Mazzini et al., 2004), carbonate platforms populated by photosynthetic microbial mats (Hips and Haas, 2006), shallow-water deposits affected by seasonal over-riding between different microbial communities (Gerdes, 2007), inter-supratidal mat-rich hypersaline environments (Mastandrea Adelaide et al., 2006) and intratidal sandy deposits (Noffke, 2009). Thus the crinkly laminated chert facies are affine to planar stromatolite growth that can be found in a range of palaeoenvironments and palaeodepth associated with phototrophic and/or chemotrophic microbial communities.

Botryoidal or colloform silica precipitates in cavities and veins are a common feature of Palaeoarchaean greenstone belts and they have been reported from a range of lithologies and environmental settings. Although the origin of such structures in the Palaeoarchaean have not yet been the target of a focused investigation, interpretations for their occurrence have been proposed, or implied, relating them to dissolution, non-hydrothermal, evaporitic processes (Tice and Lowe, 2006b; Sugitani et al., 2013) or to hydrothermal fluid circulation (Paris et al., 1985a; Van Kranendonk, 2006; Hofmann and Bolhar, 2007c; Ledevin et al., 2015). Thus, similar to the above described mat-constructing community, a range of water depths and depositional conditions could have been responsible for the presence of the fenestrae-like structures and thin stratiform cavities characterized by a colloform silica precipitate observed in the crinkly laminated chert. This may have formed very early in the history of the deposit when the sediments were still soft. As suggested by the nomenclature used so far, the fenestrae-like cavities are affine in their morphology to irregular or laminoid fenestrae that typically occur in shallow-water intertidal carbonate deposits as the result of gas entrapment,

organic decay or sediments shrinkage (Tucker, 2009). Laminoid fenestrae, particularly, are characteristic of planar stromatolites where they occur after organic matter decay, desiccation and parting of laminae (Tucker, 2009). The interpretation of the crinkly laminated facies as a planar biosedimentary deposit, the laminoid shape of the quartz-filled cavities and the associated parting of microbands may thus support a peritidal depositional environment for the mat-facies. However, sedimentary structures unequivocally supporting such a shallow peritidal environment have not been observed during this study and furthermore the scarce granular material is composed of irregular CM-rich grains that lack a true detrital component and may have been generated locally by means of processes other than current activity and erosion at the seafloor (see 3.2.4 Granular carbonaceous chert). The similar paucity in hydraulically reworked material has been observed in previous studies on the BRC shallowplatformal lithofacies for which the depositional depth has been inferred from about 15 m deep down to the storm wave base (Tice and Lowe, 2006b). Furthermore, fenestrae or other similar irregular cavities are known to form below the peritidal zone even in deep-water deposits (Shinn, 1983; Pratt, 1995; Elrick and Snider, 2002; Tucker, 2009), as a consequence of degassing vesicles in deep-water methane seepages (Mazzini et al., 2004) or resulting from hydrothermal karst after soluble minerals such as limestones, dolomite or gypsum (Tucker, 2009). The latter case seems to closely resemble the crinkly laminated ferruginous facies as both fenestrae-like cavities and stratiform veins are characterized by a botryoidal quartz infilling which is commonly precipitated into vugs and veins after silica-rich hydrothermal fluids in low-sulfidation epithermal systems (Marchev et al., 2004; Marinova et al., 2014), marine seepage (Mazzini et al., 2004), or also sinters at subaerial and sublacustrine hotsprings (Fournier et al., 1991; Guido and Campbell, 2012), with those environments representing viable settings for mat-forming microbial life (Fayers and Trewin, 2003; Trewin et al., 2003; Mazzini et al 2004; Guido and Campbell, 2012). The possible interaction of unconsolidated crinkly laminated sediments with pervasive silica-rich fluids could explain the occurrence of locally disrupted and plastically intruded microbands rich in granular reworked material. Such CM-rich grains are, in fact, characterized by rims of spherulitic precipitate, typical precipitate after hydrothermal silica colloidal fluids (Fayers and Trewin, 2003), which is instead not observed in planar undisturbed microbands. A silica-rich fluid is also consistent with the occurrence of highly silicified pale crinkly laminated microbands in the immediate surroundings of botryoidal stratiform veins as those could have represented subsurface silicification fronts. The ductile nature of the crinkly laminated facies, finally, could be the result of sediment fluidization after a pervasive silica-rich fluid that would have not percolated in the already lithified impermeable white banded cherts.

Black, dense, smooth spheres and blobs occurring in cross-cutting veinlets, but also scattered within the ferruginous bands of sample D1, display a peculiar morphology. They reflect optically and their carbon rich composition most probably indicates an originally viscous hydrocarbon phase that has now solidified into bitumen blobs, a common feature in oil reservoirs and organic rich sediments that have gone through the oil formation window (Buick, 1990; He et al., 2015; Suárez-Ruiz et al., 2016). The presence of bitumen droplets within sedimentary ferruginous microbands suggest the mobilization, at least locally, of a hydrocarbon-rich fluid phase through the crinkly laminated sediments possibly after an hydrocarbon-rich pervading hydrothermal fluid. Similar bitumen globules have been previously reported from an Australian Palaeoarchaean chert-barite unit at the North Pole locality near the base of the Warrawona Group in proximity to a chert dyke (Buick, 1990). Despite these observations constraints about the original water depth of the crinkly laminated facies deposition cannot be provided with certainty, however, early interaction between cherts and hydrothermal silica-rich fluids is strongly suggested and further discussed in the following paragraphs and chapters together with its implications for possible chemotropic life.

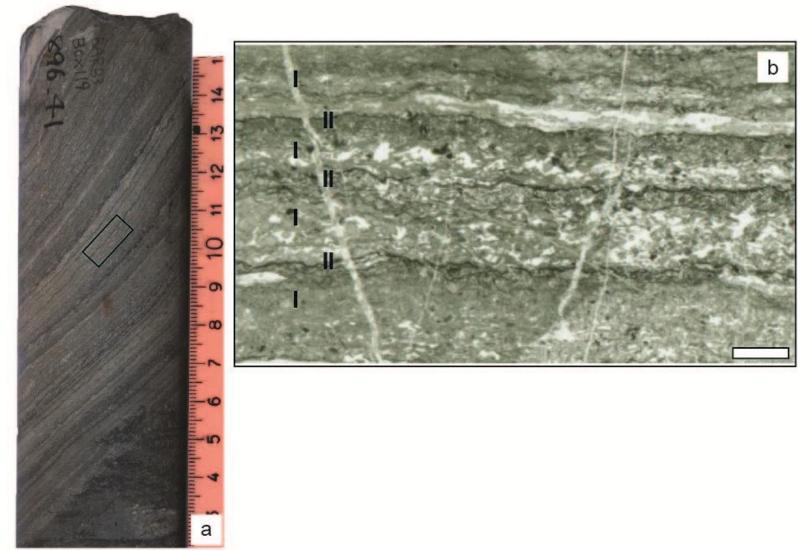


Figure 3.2 – Crinkly laminated chert. a) Sample F13 (896.59-896.41 m) is an extremely well preserved greenish-grey crinkly laminated section. b) A thin section photo from a similar site as the inset in (a). The crinkly laminated chert has a microfabric composed of alternated siderite-rich microbands (I) and interlayered thin mat-like laminations (II). Scale bar 2 mm.

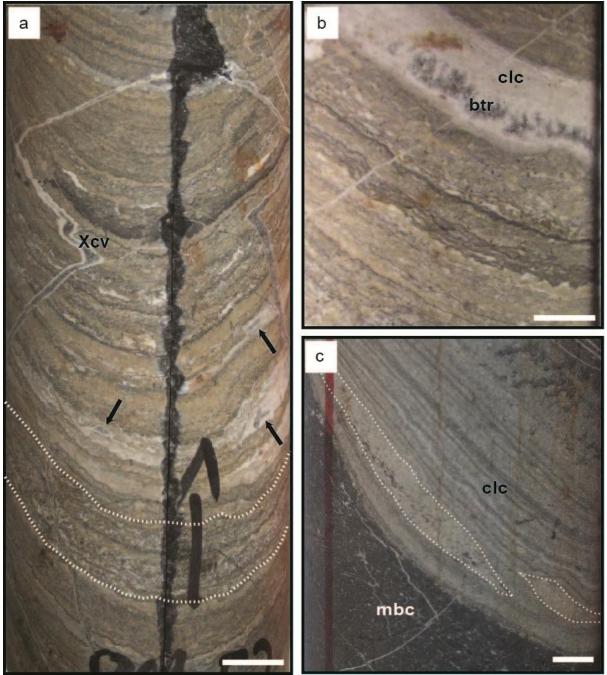


Figure 3.3 – Crinkly laminated chert (clc). a) Sample F11 (894.52-894.35 m). From the bottom to the top it is possible to observe: a group of microbands characterized by a granular texture consisting of dark grey sandy material (between the white dashed lines); a group of microbands associated to multiple botryoidal quartz-filled small cavities and fenestrae-like structures (black arrows), such microbands are softly deformed and highly silicified. Along the sample fenestrae-like structures filled by white quartz are common. The planar microfabric is often disrupted in association to both granular material and fenestrae-like structures. Upper in the core a younger cross cutting vein (XcV) occur. Scale bar: 1 cm. b) A stratiform cavity filled by botryoidal (btr) quartz precipitate occur within this crinckly laminated chert. Note the colloform bending protruding towards the cavity interior which is dusky- or grey-blue consisting of megaquartz crystals. Immediately overlying crinckly laminated microbands (clc) are almost completely silicified, nevertheless the crinkly texture is still recognizable. Scale bar: 2.5 mm c) Sample C8 (865.76-865.63 m). Lenses of granular material representing possible plastic intrusions resulting from sediments fluidization and causing soft- deformation (white dashed lines). The underlying facies is a massive black chert (mbc). The contact between the facies is a thick stylolite seam. Scale bar: 5 mm

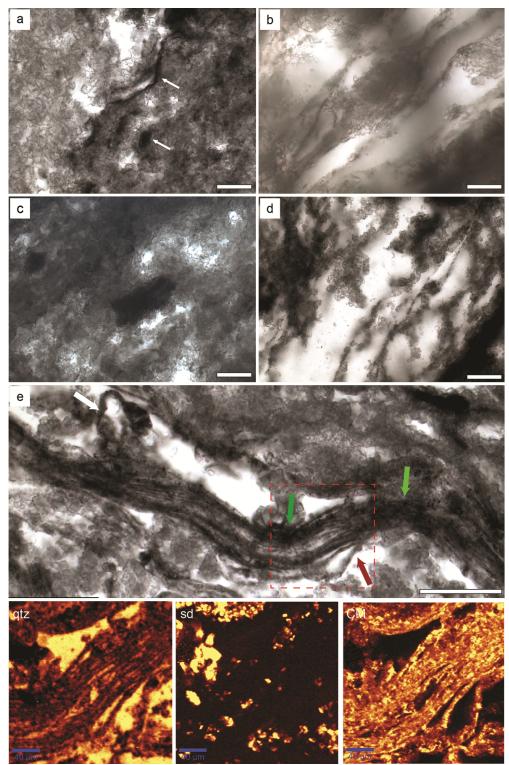


Figure 3.4 – Microphotographs of crinckly laminated chert. a) Discrete siderite-bearing microbands of sideriterich chert and CM locally forming grains and laminae (arrows). Scale bar: 100 μ m. b) CM-rich laminae gently draping siderite and composite grains. Scale bar: 50 μ m. c) Discrete grain of CM. Scale bar: 200 μ m. d) Siderite crystals associated with CM-rich laminations. Scale bar: 100 μ m. e) Carbonaceous lamina-set. Top: photomicrograph of a lamina-set. Scale bar: 200 μ m. Note the multilayered structure showing plastic and choesive behaviour including features typical of microbial mats such as folded-over or roll-up structures (white arrow) which can remain partially attached to the main structure, plastic bending (green arrows) and anastomosing layering (red arrow) around lenticular chert domains. Bottom: high-resolution Raman maps showing the quartz (qtz), siderite (sd) and carbonaceous matter (CM) distribution of the above boxed area. Note the lamina-sets composed mainly of CM in a chert cement, with siderite being scarce. Scale bars of the raman maps 40 μ m.

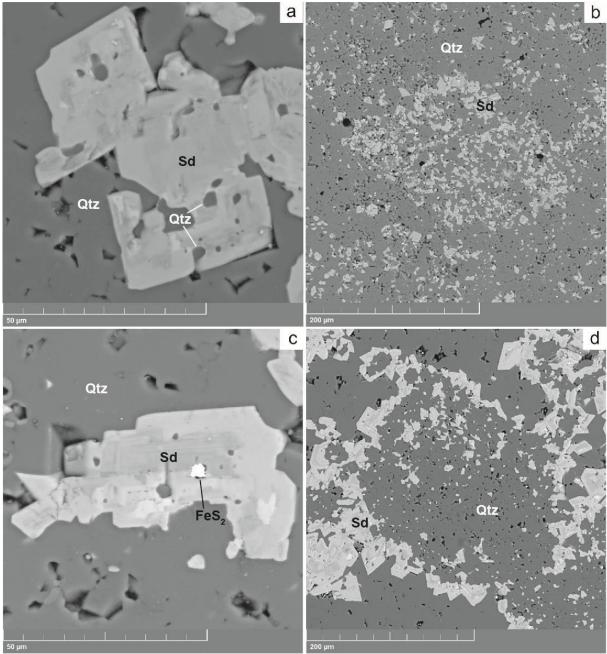


Figure 3.5 – Crinkly laminated chert. a) Rhomboidal euhedral siderite crystals (Sd) in a chert matrix (Qtz). Crystals show zonation reflecting the relative abundance of Mg, Mn and Ca. Margins of the grains are etched and the crystals are partly silica replaced. b) Disseminated siderite grains defining a large rhomboidal crystal now abundantly replaced by silica. c) A subhedral siderite crystal bear a pyrite inclusion (highly reflective mineral, FeS2). d) Siderite crystals form an ellipsoidal structure in association to a carbonaceous grain in the quartz matrix. Note that the CM forming grains and clots can't be clearly distinguished in SEM imaging.

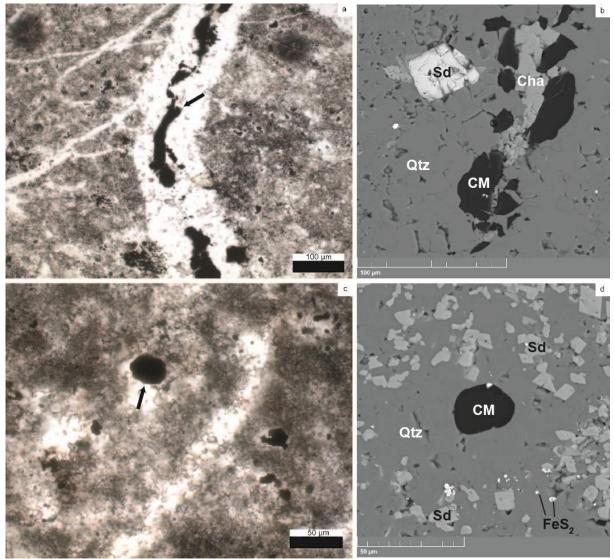


Figure 3.6 – Bituminous CM in the crinkly laminated chert, Sample D1 (896-895.9 m). a) Dense bituminous CM (black arrow) occurring as a cross cutting vein filling. b) At the SEM such carbonaceous microtexture is extremely dense (CM). Interleaved with the dense CM secondary chamosite (Cha) also occur. The rhombohedral crystal is siderite (Sd). c) Other than as a veinlet filling, dense carbonaceous smooth spheres (black arrow) and blobs are also observed scattered within the crinkly ferruginous chert. d) Bituminous blobs (CM) can be easily observed at SEM imaging, differently from the carbonaceous grains and clots. Here the smooth CM-rich blob occur in a chert matrix (Qtz) together with scattered siderite and finely grained pyrite.

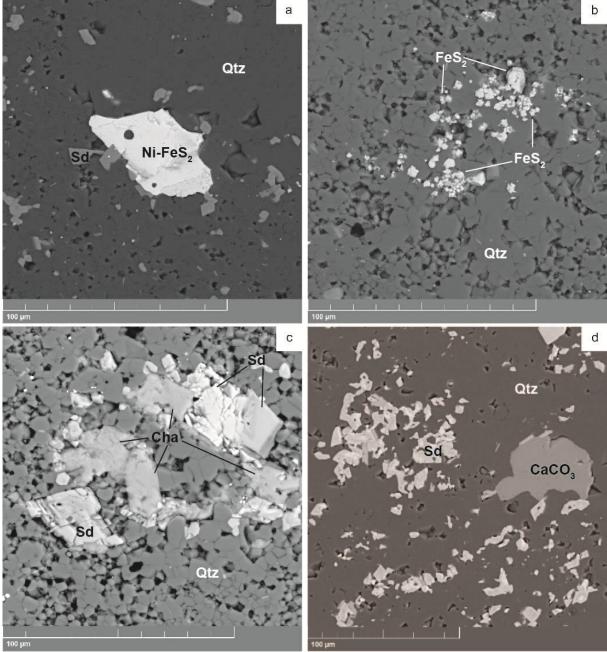


Figure 3.7 – Accessory minerals in the crinkly laminated chert. a) Two Ni-rich pyrite pseudomorphs after rhomboidal crystals in a chert matrix enriched in dispersed siderite. b) A pyrite cluster. c) Euhedral rhomboidal siderite crystals and secondary intergrowing chamosite $(Fe^{2+},Mg,Al,Fe^{3+})_6(Si,Al)_4O_{10}(OH,O)_8$. d) Calcite cement (CaCO₃) on the right, occurring in a ferruginous chert.

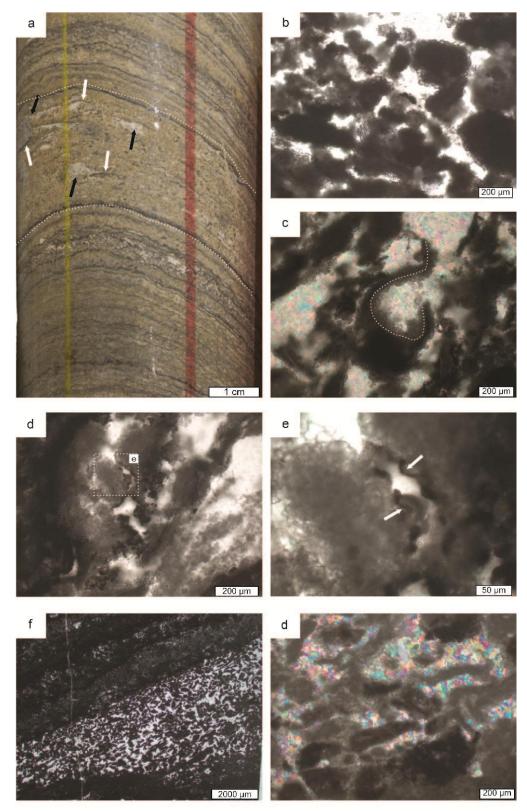


Figure 3.8 – Clc with a granular texture. a) A section of ferruginous chert, from the lower shallow facies, where the microbanded structure is disrupted (between white dashed lines) in association to botryoidal quartz-filled cavities (black arrows). CM mat-like lamina-sets fragments are observed (white arrows). In thin section such bands are characterized by CM-siderite composite grains forming a peloidal-like texture (b) and rip-up mats fragments (white dashed line) now overgrown by siderite (c). d) and (e) Silica spherulitic precipitation around CM-siderite grains is marked by CM particles precipitating within the botryoids (white arrows). f) The plastic intrusion observed in Fig. 3.3c. g) The material in the plastic intrusion is composed of rip-up fragments of CM grains and laminae derived from the ferruginous chert itself probably after sediments fluidization.

3.2.2 Massive black chert

Massive black chert (mbc) consist of homogeneous, unstructured layers, sometimes exceeding 50 cm in thickness but most commonly forming bands about 5 cm thick (Fig. 3.9). It appears particularly rich in well compacted CM, nevertheless white to grey silica filled pores and small irregular cavities up to some millimetre in size, can be observed scattered through the bands especially at the base of the BARB3 (Fig. 3.9). Black massive layers in the studied samples are characterized by unconformable contacts with the adjacent chert facies consisting of well developed wave-like sub-planar stylolites having thick seams enriched in dark CM and sulphides (Fig. 3.9c). Numerous quartz and chlorite-filled veinlets also crosscut the facies at different angles, the latter not extending to the adjacent facies.

3.2.2.1 Microfacies description

In thin section the massive black chert is structureless and appears as a carbonaceous continuum, in a chert matrix, interrupted by disseminated chert-filled pores and elongated cavities (Fig. 3.9b,c and Fig. 3.10a). The cavities are generally a few hundred microns long, some consist of silica-replaced rhomboidal and tabular pseudomorphs possibly after carbonates and anhydrite respectively (Fig. 3.9b,c and Fig. 3.10a). Numerous cross-cutting veinlets occur and other than quartz they are characterized by abundant chlorite infillings (Fig. 3.10b). Tentative grains consist of CM cloudy aggregates having a size typically around 200-250 µm, those can be rounded or irregular (Fig. 3.10a), however with such a poor preservation it is not clear if their morphology is primary, or results from processes such as CM mobilization and displacement during chert crystallization (Pflug, 1967). Diverse CM microtextures also occur (Fig. 3.10), so that massive black chert has a various carbonaceous assortment. Other than cloudy diffuse particles and aggregates a more dense amorphous carbonaceous phase can be observed interspersed between the chert grains within the chertfilled pores an cavities (Fig. 3.10c). However such microtexture may be more diffused, although masked by the carbonaceous cloudy dark haze. Dark, thick and unstructured, interstitial between chert grains it differentiate from morphologically defined mats and grains but also from the cloudy diffuse CM particles. From optical observations it is suggested that this CM microtexture represents originally a suspended fluid sealed within a crystallizing silica-rich mass. Such CM is often closely associated with fine euhedral pyrite crystals and pyrite clusters. Bituminous CM, of the type already reported for the crinkly laminated

ferruginous sample D1 (Fig. 3.5c,d), is frequent in the massive black chert, mainly found in stylolite seams (Fig. 3.10f), as a veinlet infilling and in the form of disseminated smooth spheres and blobs a few microns in size (Fig. 3.10d), usually associated with scattered authigenic cubes or particles of pyrite (Fig. 3.10e).

In thin section, the massive black chert in the BARB3 CM-rich facies is also characterized by a greater abundance of sulphides and chlorite. Pyrite, often Ni-bearing, is the most common sulphide and it can be observed as a secondary replacing mineral after rhomboidal pseudomorphs (Fig. 3.11a), frequently with co-occurring chamosite, as scattered fine-grained cubic authigenic crystals (Fig. 3.10e), or finely-grained clusters (Fig. 3.11a). Arsenic Co, Ni-rich subhedral sulphides occur more rarely (Fig. 3.11b). Acicular, or columnar finely dispersed chamosite is particularly rich in the massive black chert (Fig. 3.11c,d,e). Although often obscured by the diffuse CM, it can be observed distributed through the whole volume of the thin section (Fig. 3.11c,d,e). Finally, rare replacement Ti-oxides associated with secondary chamosite have been also detected using SEM-EDS (Fig. 3.11b).

As seen directly along the core, wave-like stylolites are a peculiar feature of the massive black chert. Sub-planar wavy dissolution seams occur at the contact with the adjacent facies, however minor stylolites occur also at an angle to the sedimentary bedding within and limited to the massive black facies. SEM-EDS analysis shows that the stylolites are composed of a complex and dense thick mixture of bituminous CM, copious Ni-pyrite clusters and euhedral crystals, similarly occurring various arsenic Co, Ni-rich sulphides, chamosite and more rarely titanium oxides (Fig. 3.12).

3.2.2.2 Interpretation

Like the bedded and finely laminated microcrystalline quartz deposits, massive black chert is a recurring facies in Palaeoarchaean volcano-sedimentary successions. Depending on the internal texture, composition, and depositional settings, massive black chert have been associated with bedded black carbonaceous sedimentary layers (Walsh and Lowe, 1999; Sugitani et al., 2015) or carbonaceous-rich veins and dikes of hydrothermal origin (Kiyokawa et al., 2006; Hofmann et al., 2013b).

The BARB3 massive black chert lacks sedimentary structures both along the core and internally. A continuous carbonaceous haze including diffused and diverse CM microtextures, scattered sulphides and finely dispersed acicular chamosite, characterizes the facies. Individual carbonaceous grains are barely recognizable and by morphology they cannot be

directly compared to grains in the other BARB3 CM-rich facies or to younger CM clotted microbial textures (Fayers and Trewin, 2003; Trewin et al., 2003). Carbonaceous laminae are absent, indicating that no mat-construction was involved in the deposition of this facies. Although occurring in stratiform bands, massive black chert can't be conformably related to the adjacent layers as pressure-dissolution processes have obliterated the original contacts and the material lacks evidence of detrital components or any traces of sedimentary laminations. Thus textural evidence does not support a bedded sedimentary origin for this facies.

On the other hand the lack of detrital grains and sedimentary structures bears a greater similarity with the texturally similar massive black chert previously reported from Palaeoarchaean carbonaceous dikes and hydrothermal veins (Ueno et al., 2004; Kiyokawa et al., 2006; Hofmann et al., 2013b). The massive black chert facies of the BARB3 in thin section is characterized by a greater abundance in authigenic pyrite, sulphide clusters and chamosite, whereas sulphides are a common and conspicuous precipitate in hydrothermal veins (MacLean and Kranidiotis, 1987; Hannington et al., 2001) and chamosite is a typical product of rocks hydrothermal alteration (Kranidiotis and MacLean, 1987; Kamenetsky et al., 2002). Such enrichment is reflected by the characteristic occurrence of thick and sealed stylolites seams that formed due to the abundance of these slowly dissolving phases. Quartz filled cavities which in sedimentary massive black cherts have been interpreted as fenestrae (Sugitani et al., 2015), here are often geometric, reflecting quartz substitution after a former mineral phase, rather than a void formed due to sediment shrinkage or decomposition of possible organic debris. The observed irregular, non-geometric, cavities however, are consistent with a porous original facies. Similar evidence has been presented regarding the lack of compaction for black chert veins in the BGB (Hofmann et al., 2013b). The interpretation of the BARB3 massive black chert as a vein facies may explain the presence of possible quartz pseudomorphs after anhydrite. This is a common precipitate in hightemperature vents (Zhang, 1986; Hannington et al., 2001; Chambefort et al., 2008) but also in mixing low-temperature hydrothermal fluids with seawaters (Bischoff and Seyfried, 1978; James and Elderfield, 1996), and may have provided a sulphur source for the abundant authigenic pyrite. If the massive black chert was deposited as a vein, some of the more regular quartz-filled cavities may also represent silicified fragments ripped-off from the host rock walls due to hydraulic fracturing.

Massive black chert includes a peculiar and diverse CM microtextural assemblage. Morphologies clearly suggesting a possible microbial origin are absent, however disrupted and irregular cloudy carbonaceous aggregates, about 200 µm in size, indicate the CM may have been individual clots originally, now altered almost beyond recognition. Most of the diffuse amorphous cloudy material could represent the relicts of such original clots.

Further CM microtextures occur as dense infillings between microcrystalline quartz grains and in the form of bituminous optically reflective blobs, spheres and veins infilling. As already documented for the crinkly ferruginous chert sample D1, the black bituminous material probably represents an original viscous hydrocarbon phase (Buick, 1990; He et al., 2015; Suárez-Ruiz et al., 2016) and similarly, the dense infilling within the chert matrix appears to be derived from a fluid phase. The co-occurrence of dense carbonaceous infillings and bituminous material often in association with authigenic sulphides suggest an hydrothermal fluid phase mobilizing metals and viscous hydrocarbon materials, whereas the production of hydrocarbon and its mobilization in a fluid phase is consistent with hydrothermal activity (Mazzini et al., 2004). The lack of detrital components, sedimentary structures, the mineralogical composition and the carbonaceous microtextures suggest that the BARB3 massive black chert may be better interpreted as a massive carbonaceous hydrothermal activity.

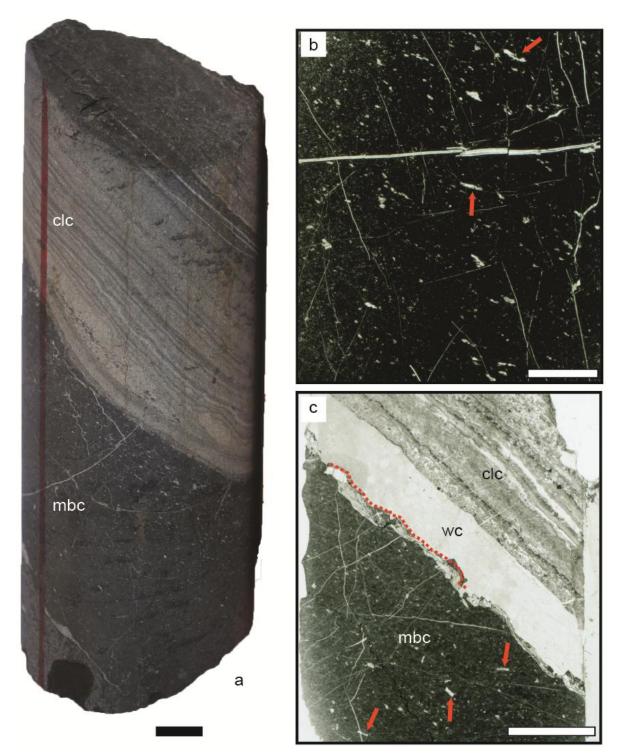


Figure 3.9 – Massive black chert. a) Sample C8 (depth along the core, 865.76-865.63 m) include a lower massive black chert (mbc). This facies is unstructured consisting of dense massive carbonaceous chert, however some porosity is preserved in the form of quartz-filled cavities, although many of those are actually chert pseudomorphs after other large crystals (see also b,c). The upper contact with the overlying crinkly laminated chert (clc) consist of a wave-like stylolite similar to the one observed in thin section on the right (c). b) In thin section the massive black chert is also unstructured. Quartz filled pores occur as well as many quartz pseudomorphs after tabular crystals or clasts (red arrows). Porosity and clasts appear parallel to the bedding. c) A thin section of the contact between a massive black chert and an overlying white chert band show pressure-dissolution manifested in the form of a thick wave-like stylolitic seams (red dashed line). Upper in the section a white chert (wc) and crinkly ferruginous chert (clc). Scale bar for all the figures: 1 cm.

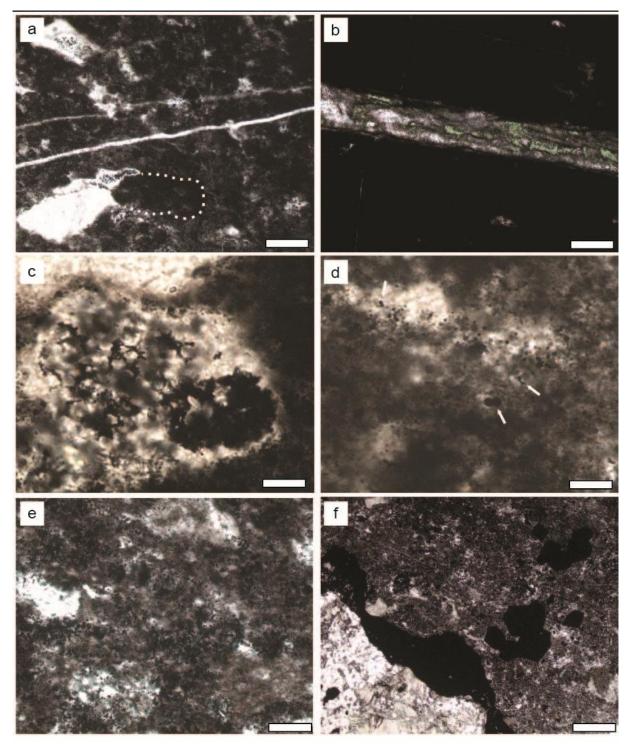


Figure 3.10 – Massive black chert. a) The facies consist of cloudy diffuse CM interrupted by chert-filled pores, cavities and cross-cutting veins. Cavities are often regular and represent quartz pseudomorphs after rhomboidal or tabular geometries. In this figure the upper cavity represent a long tabular pseudomorph partially replaced by CM and superimposed by a quartz pseudomorph after a rhomboidal crystal. The lower cavity has a regular rhomboidal shape. A tentative carbonaceous grain is marked by the dashed white line. Scale bar: 200 μ m. b) A cross cutting vein filled by quartz and green chlorite (chamosite). Scale bar: 200 μ m. c) Dark, thick interstitial CM is typically observed interfingering between chert grains in quartz-filled pores and cavities. Scale bar: 20 μ m. d) Spheres of bituminous CM are found scattered within the CM. Note that due to the richness in cloudy CM those carbonaceous microtexture can be recognized only in some area. Scale bar: 20 μ m. e) Scattered black dense tiny particles consist of copious finely dispersed pyrite grains and bituminous CM. Scale bar: 50 μ m. f) At the contact between massive black chert and an underlying white chert a thick wave-like stylolite is found enriched in dark material consisting mainly of bituminous CM, sulphides and chlorite. In the massive black chert euhedral hexagonal and cubic authigenic pyrite occur. Scale bar: 200 μ m.

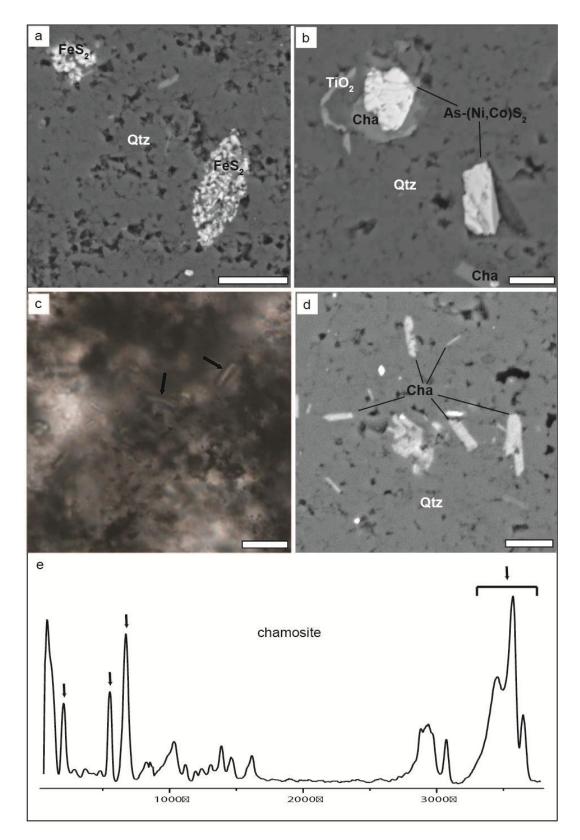


Figure 3.11 – Massive black chert. a) A cluster of finely grained pyrite in a rhomboidal pseudomorph. Scale bar: 20 μ m. b) Two arsenic Co, Ni-rich subhedral sulphides in a chert matrix. The sulphide on top is intergrown by secondary chamosite (Cha), and on the left a lamina rich in TiO₂ occur. Scale bar: 10 μ m. c) Optical and SEM (d) imaging on finely dispersed acicular or columnar chamosite(black arrows and Cha) which is particularly abundant in the massive black chert. Both scales are 10 μ m. e)The peculiar Raman peaks used to identify the columnar chamosite are pointed by the black arrows. The other peaks represent the pattern for the contaminant epoxy resin

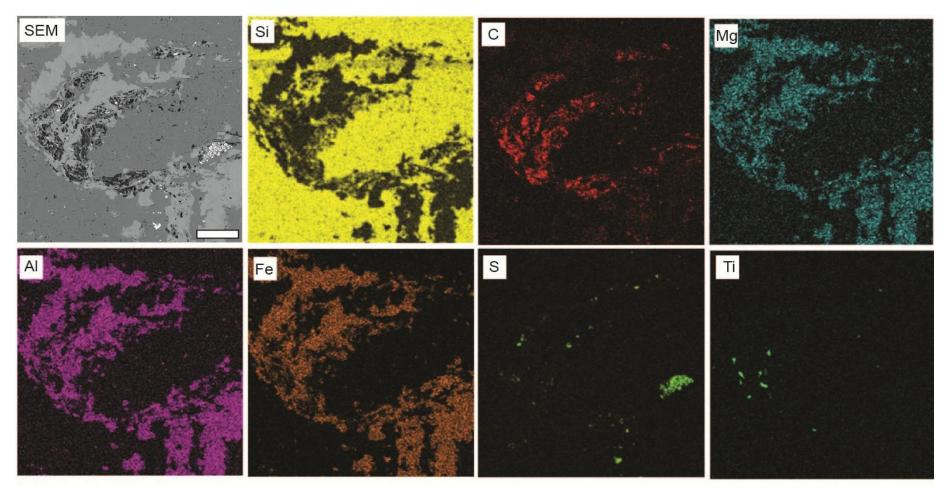


Figure 3.12 – Elemental distribution in a wave-like thick stylolite occurring at the interface between a massive black chert and a different chert facies. Scale bar: 60 µm.

3.2.3 Laminated black chert

At a first glance laminated black chert (lbc) strongly resemble massive black chert both in its aspect and distribution along the core. As for the massive carbonaceous facies, laminated black chert is an extremely homogeneous dark facies characterized by white-grey silica filled pores and small irregular cavities (Fig. 3.13a,c). However it differentiate, as suggested by its name, being composed of superimposed individual carbonaceous rich laminations, commonly a few millimetre thick (Fig. 3.13a,b). Those are separated by extremely thin (less than 1 mm) white-grey quartz layers which are very difficult to distinguish at the naked eye but even in thin section. Nevertheless another feature may help the distinction as along the core laminated black chert layers are found conformably interlayered with the ferruginous-and-white banded facies while as seen before massive black chert is characterized by thick pyrite-rich stylolitic seams indicative of sediment dissolution. Furthermore laminated facies appear also slightly more granular and porous in their texture (Fig. 3.13a).

3.2.3.1 Microfacies description

In thin section laminations are also difficult to distinguish (Fig. 3.13c). However modes of CM deposition and mineralogy are slightly distinct from what observed in the massive black chert. Laminated black chert observed during this study consist of a mixture of randomly oriented carbonaceous grains and diffuse CM within a microcrystalline quartz cement (Fig. 3.14a), with scarce scattered authigenic cubic pyrite crystals and finely dispersed chamosite. As described above for the other carbonaceous rich facies, discrete carbonaceous structures, when observed at high-magnification, consist of sub-micron sized CM particles in a pervasive microcrystalline quartz matrix. Simple grains ranging from a few microns up to ~500 µm predominate in laminated black chert (Fig. 3.14a,b). They consist of fluffy dense concentrations of CM characterized by irregular shapes and margins and showing no evidence of compaction (aspect ratio < 10). Discrete wisps and composite grains also occur with less frequency. The first consist of dense elongated carbonaceous flakes (aspect ratio > 10) up to a few hundred microns long and often less than 10 µm thick resembling carbonaceous laminae (Fig. 3.14c) but differentiating from the latter by their uneven lateral thickness, the lack of continuity and absence of anastomosing behaviour. Composite grains (Fig. 3.14b) represent simple carbonaceous grains aggregated into discrete clumps which reach up to $\sim 1000 \ \mu m$ in

size. Dense CM is also observed forming botryoidal rims around discrete grains or as dense, opaque, cavity-filling, interstitial material between grains or between the domains of composite grains (Fig. 3.14b). As for the ferruginous crinkly laminated chert, cross-cutting mainly sub-vertical quartz veinlets often infilled by a dense bituminous CM phase occur in the laminated black chert (Fig. 3.14c). This CM was deposited from a fluid phase and the cross-cutting nature of veinlets is indicative of later fracturing events.

3.2.3.2 Interpretation

Similarly to the black massive facies, the laminated black chert provide scarce textural features that can be used to infer a model for its origin. It is roughly massive and bears a mineralogical composition consisting mainly of CM, scattered sulphides and dispersed chlorite. However the laminated black chert is conformably interlayered with the ferruginous and white banded sediments suggesting its sedimentary origin. The planar laminated texture, the lack of other sedimentary structures, the absence of rounded grains, clastic material or other clear evidence of transportation, suggest a deposition in a low-energy environment. As no carbonaceous laminae have been observed, growing by mat-construction is discredited, and the black laminated chert facies fit better with a cyclic gentle precipitation of fluffy carbonaceous grains out of the water column. Such interpretation is consistent with precipitation of organic debris after microbial activity in the water column or deposition out of carbonaceous rich exhalative fluids during intervals of volcanic quiescence like previously suggested for other Palaeoarchaean laminated black chert (Walsh and Lowe, 1999; Kiyokawa et al., 2006; Hofmann and Bolhar, 2007c). The irregular fluffy carbonaceous grains and wisps are similar to younger microbial clotted textures (Fayers and Trewin, 2003; Trewin et al., 2003) suggesting a possible biological origin.

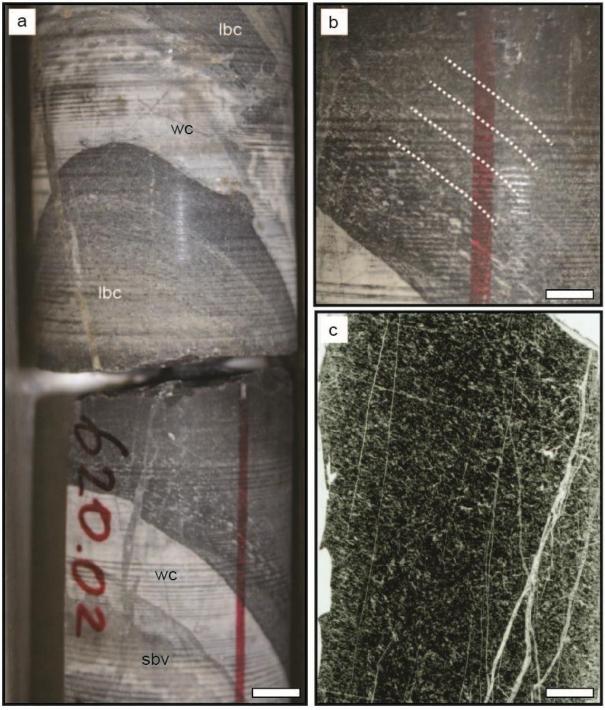


Figure 3.13 – Laminated black chert. a) Sample C2 (620.17-620.02 m) include a thick laminated black chert mesobands (lbc). It is a very homogeneous dark facies characterized by white-grey silica filled pores. The top of the carbonaceous rich band show clear evidence of sedimentary lamination. At the bottom of the sample a botryoidal quartz-filled stratiform vein (sbv) is capped by a white bedded chert band (wc). The laminated black chert is overlaid by a white chert band (wc) and possibly more black laminated chert (lbc). Scale bar: 1 cm. b) An enlarged section of the sample C2 where a white dashed line is used to highlight the individual sedimentary laminations which are not always of easy identification. Scale bar: 5 mm. c) A thin section from the sample C2 show the very homogenous carbonaceous rich character of the laminated black chert. Scale bar: 3 mm.

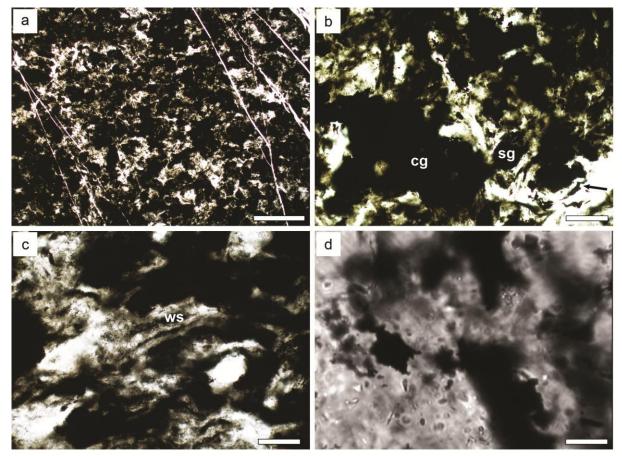


Figure 3.14 – Photomicrographs of laminated black chert. a) Laminated black chert is composed mainly of randomly oriented, equant simple carbonaceous fluffy grains, but also composite carbonaceous grains and wisps. The fabric is cross-cut by later quartz veinlets. Scale bar: 1000 μ m. b) A large composite carbonaceous grain (cg) and several simple carbonaceous grains (sg) are present in chert precipitate. The black arrow at the bottom right corner points at a botryoidal CM-rich rim that can often be found around simple or composite grains. Scale bar: 200 μ m. c) Elongated wisps (ws) of CM which can be so thin that they may resemble mat-like carbonaceous laminae. Scale bar: 100 μ m. d) Dense CM present from cross-cutting quartz veinlets similar to those seen in (a). Scale bar: 20 μ m.

3.2.4 Granular carbonaceous chert

The granular carbonaceous chert (gc) is a poorly sorted mixture of abundant sandy carbonaceous grains and rare scattered white, black and greenish-grey pebbles and clasts that can reach dimensions up to a few centimetres (Fig. 3.15a,b). It is a detrital facies and it always occurs as a filling within botryoidal quartz stratiform veins, resulting in a geopetal structure (Fig. 3.16). Such association along the core is consistently found interbedded between an underlying crinkly laminated ferruginous chert (sometimes even just a single microband) and an overlying white bedded chert, so that the way-up succession of crinkly laminated chert-granular carbonaceous chert-botryoidal quartz vein-white bedded chert represents a recurring pattern through the BARB3 core (Fig. 3.15a,b and Fig. 3.16).

The contact between the granular chert and the underlying crinkly laminated facies is erosional and associated with the disruption and soft-deformation of the ferruginous microbands (Fig. 3.15b and Fig. 3.16). The crinkly microbands can be found plastically deformed (Fig. 3.16c) and partially uplifted so that fringes of the clc bands float in the overlying granular carbonaceous material. Crinkly laminated rip-up fragments occur within the granular chert (Fig. 3.15b, Fig.3.16). They are typically large at the base of the granular thickness. Here they sit at the erosional contact, usually parallel to the bedding, close to their site of origin and sometimes form possible imbrication structures (Fig. 3.16b). At the top of the granular chert, the size of such clasts generally decrease. The smaller fragments float in the sandy material usually parallel to bedding and their provenance can't be faithfully reconstructed also due to the limited size of the core. Crinkly laminated microbands that have been lifted-up or disrupted and now float in the granular chert have typically lost their greenish hue and appear to be entirely silicified. The granular chert also includes white or grey coarse chert sandy grains and pebbles that are usually rounded. Less frequently black carbonaceous rich clasts and pebbles can be observed dispersed in the sandy carbonaceous chert (Fig. 3.15a).

Representing the bulk of the facies, the coarse and poorly sorted sandy carbonaceous grains fill all the spaces available around the lifted-up microbands and the rip-up clasts. Close to the lower contact, the sandy material shows greenish-grey patches similar to the underlying ferruginous bands suggesting that here some siderite may be present. The granular carbonaceous chert forms stratiform thicknesses that range from less than 1 mm, composed of fine sandy material only, to a few centimetres, often including large rip-up clasts. Well compacted centimetre thick layers along the core may show evidence of internal bedding

forming individual laminations a few mm thick indicating that the facies was piled up during several phases of detrital input (Fig. 3.15a).

The upper contact of the granular facies is irregular and it is coated by the lower colloform banding of the overlying botryoidal quartz-filled vein. The botryoidal quartz filled vein is characterized by the colloform silica precipitate protruding towards the cavity centre and by a transition from marginal white quartz towards a dusky-blue mega quartz (Fig. 3.15, 3.16, 3.17a), similar to stratiform cavities in the crinkly laminated chert. The roof of the vein always consist of a white chert band, occasionally greenish chert fragments hang down from the white chert band; such fragments appear to be affine by texture and composition to the crinkly laminated bands observed, in the same veins, at the base of the granular chert (Fig. 3.16a,b).

The occurrence of botryoidal quartz-filled chert veins and granular carbonaceous chert is often associated to the local brecciation or tensile failure of white chert bands in the immediately underlying core bands (Fig. 3.16c). In these cases the granular material tends to move downwards, filling fractures and open spaces demonstrating the plastic and intruding attitude of such cavity filling facies. Fragments of the fractured white chert bands may be displaced and incorporated into the granular facies. Brecciated fragments of white chert, even still in place, show evidence of roundness (Fig. 3.16c).

3.2.4.1 Microfacies description

Apart from some siderite at the base of the facies (Fig. 3.17f), rare secondary chamosite and quartz rhomboidal pseudomorphs possibly after carbonates, the granular carbonaceous chert is almost entirely composed of carbonaceous grains in a chert matrix (Fig. 3.17b). As observed along the core, disrupted, softly-deformed and typically highly silicified layers of crinkly laminated facies occur at the base of the granular chert (Fig. 3.17d). Immediately above, the bulk of the granular facies is composed of sandy carbonaceous material consisting mainly of fluffy equant carbonaceous grains and clot aggregates (Fig. 3.17b,c); wispy grains are less frequently observed. The sandy carbonaceous material varies in dimension, encompassing grain size from silt to very fine gravel. Large carbonaceous-rich or white quartz rounded pebbles up to a few centimetres occurs. Rip-up fragments mainly of crinkly laminated chert (Fig. 3.17d and Fig. 3.18a) facies but also of more carbonaceous rich beds, possibly black laminated chert, are found scattered within the sandy material. At the base of the granular chert, rip-up fragments of mat-like laminations (Fig. 3.18 a,b,c,d) float in the quartz matrix maintaining their original cohesiveness and plastic behaviour, forming rolled-up and folded over structures. Always at the base of the facies close to the underlying ferruginous chert, CM clots and laminae are associated to finely grained siderite (Fig. 3.17f). Siliceous rounded grains, ranging between 100 and 200 μ m, appear in this facies (Fig. 3.17e). Both carbonaceous and siliceous grains are characterized by rims of botryoidal silica precipitate enriched in dense CM (Fig. 3.17c), like previously observed in the black laminated chert (Fig. 3.14b).

In thin section the laminated texture of the granular carbonaceous material can be observed (Fig. 3.18a). The top of the granular chert is coated by a characteristic silica colloform precipitate forming a botryoidal isopachous lamination (Fig. 3.15b and Fig. 3.17a) which can be a few mm thick and it is composed by an alternation of thin dark carbonaceous rich and poor white chert laminae. The lamination is thus capped by a thin layer of coarser quartz crystals which after a few hundred microns turn into the megaquartz crystals which make up the main part of the veins filling.

At the bottom of the quartz-filled veins is a very peculiar CM microtexture, that has been observed in several samples existing on top of the microcrystalline isopachuous botryoidal lamination. It clearly differs from the CM observed in the granular chert, as well as from the botryoidal laminations and consists of a carbonaceous network up to 100 µm thick which gently coat the fine colloform precipitate immediately overlying the sandy detritus (Fig. 3.18 a,f,g,h,i). Although often disrupted and fragmented the carbonaceous network can extend for several mm or even throughout the thin section width, draping the bedded colloform thickness. At high magnification (Fig. 3.18 g,h,i) it consists of a continuous interconnected web of CM that appears to be trapping rounded, typically elongated silty or very fine sandy quartz grains. Such grains are packed together and preferentially oriented along the bedding plane (Fig. 3.18 g,h,i). The carbonaceous network shows an overall plastic and trapping behaviour which suggest it was originally a cohesive substance.

3.2.4.2 Interpretation

It is clear from the sedimentological textures described above that the granular carbonaceous chert represents a detrital component consisting of a mixture of carbonaceous grains and clasts derived from the erosion and reworking of material originally deposited in other primary sedimentary settings. The majority of the detritus appears to have originated from the ripping-up and reworking of crinkly laminated ferruginous chert facies. This is

evident as the granular chert consistently occurs on top of an eroded and softly deformed ferruginous laminated band and includes mainly individual irregular carbonaceous clots and clot aggregates, crinkly laminated rip-up fragments, rip-up and rolled-over lamina-sets and CM-siderite composed grains thus reflecting the textural and mineralogical composition of the underlying facies. Additional grains and clasts may have come possibly from black laminated chert facies, and from the white chert bands, probably derived from the reworking and rounding of the white chert brecciated fragments usually associated to this facies. However is not always possible to unequivocally retrace the origin of the granular material.

The granular carbonaceous chert is puzzling with respect to its origin and many questions raised during its investigation. What would have been the stress or the source of energy responsible for the ripping up, reworking and mixing of such coarse and poorly sorted material? Where did the such process took place, at the seafloor or in the subsurface, and at which stage in the depositional history? Why are the granular facies virtually always associated with the botryoidal quartz-filled vein and frequently with the underlying white bands that are found fractured? What is the significance of this, cyclic recurring pattern where the granular material consistently sits on a crinkly laminated facies and the colloform cavity is capped by a band of white chert?

As observed along the BARB3, the shallow-platformal lithofacies bears no evidence for strong current activity at the seafloor, as the core is lacking detrital material and current induced sedimentary structures. This is consistent with facies deposition in a very low-energy shallow-water environment. The occurrence of granular chert exclusively as a cavity filling material in such an environment suggests that this facies formed in the subsurface rather than at the seafloor during storm events, as in the latter case one would expect similar material conformably interbedded between the ferruginous and white chert and not only filling colloform cavities. The origin of the botryoidal stratiform veins in the subsurface is supported by the occurrence of greenish laminated chert fragments hanging from the roof of the veins (Fig. 3.16a,b), conformably overlaid by the banded white chert. Such ferruginous fragments are also texturally conformable with the greenish-grey bands found at the base of the granular component, indicating that originally crinkly ferruginous bands were directly overlaid by the white chert that now represents the cavity roof. Thus the botryoidal cavity with its granular chert represents a later introduced offset in the original stratigraphy that consistently occurs between the crinkly laminated chert and the overlying banded white chert.

Although the granular chert includes regular, tabular clasts ripped-up from the crinkly laminated chert, non-rigid, plastically deformed disrupted microbands have also been observed together with folded over mat chunks. This indicates that the ripping-up and reworking occurred early in the history of the deposit or at least when the crinkly laminated chert was not yet completely lithified. This is also supported by the occurrence of copious carbonaceous clots in their original irregular form and not as rigid fragments possibly rounded by mechanical friction, unlike the white pebbles which may have been derived from the brecciation of the already lithified white banded chert.

It has been proposed that the botryoidal quartz-filled cavities of the BRC shallowplatformal facies originated in non-hydrothermal settings, from the dissolution of evaporites in the phreatic zone, or as fluid escape structures resulting from soft-sediment disruption after storm events in the deeper platformal facies (Tice and Lowe 2004, 2006). Both processes are consistent with a subsurface origin for the botryoidal cavities but both processes cannot justify the occurrence of the copious amount of granular material exclusively filling cavities as observed in the BARB3 during this study. Whether the cavity originated due to shrinkage of sediments, or evaporite dissolution, an eroding and reworking force would have been necessary to produce the sandy material. In non-hydrothermal conditions the force would have come from current or wave activity at the sea-floor, but in this case, as for the storm events, one would expect copious detrital material deposited at the seafloor and not only in the subsurface cavities. Although sediment dehydration and shrinkage, evaporite dissolution and storm events are all possible causes for the formation of the cavities, such processes alone fail in justifying the exclusive presence of granular chert as a cavity filling facies.

Hofmann and Bolhar (2007) provided an extensive description of the processes and dynamics that could have led to the formation of hydrothermal dykes and stratiform veins in the BGB, including the origin of the filling detrital material. In their model, upwelling hydrothermal fluids encountering non-permeable silicified horizons would have generated an overpressure resulting in the opening of lateral stratiform veins through more porous and permeable paths. This model appears to fit the observations reported here on the BARB3 botryoidal veins and granular chert. Firstly, other than producing an offset in the stratigraphy, a hydrothermal fluid that laterally pervades buried sediments could also justify the absence of detrital material on the seafloor and their localization instead within stratiform veins. As observed along the core the sandy carbonaceous material occurs in a recurring pattern represented by the succession of crinkly laminated chert-granular carbonaceous chert-botryoidal quartz-filled vein-white chert band. Such a pattern is consistent with the white chert cavity roof representing a non permeable early silicified cap that would have forbidden vertical fluid escape forcing it laterally through the more permeable non-completely lithified

crinkly laminated chert. Thus the fluid would have been forced by a non-permeable silicified cap through lateral preferential paths represented by more permeable lithologies as suggested by Hofmann and Bolhar (2007). The granular chert would have then been derived from the brecciation, erosion and ripping-up of material from the ferruginous facies due to the pervading silica-rich fluid. The same fluid would have also been responsible for the increased silicification of ferruginous clasts and layers interested by the process, as observed at the core facies and microfacies. The laminated texture observed in the granular material is consistent with pulses of pervasive fluid, as previously reported in dykes and veins of the BGB (Hofmann and Bolhar, 2007).

The co-occurrence of stratiform botryoidal veins and granular chert fit better with the convection of hydrothermal silica-rich fluid in a sediment column characterized by heterogeneous permeability. Although this doesn't exclude the possibility that cavities may have formed by different processes in different circumstances, it is strongly suggested that an up-welling of low-temperature silica-rich fluid had a pivotal role, considering that the colloform silica precipitate, as already discussed earlier in this chapter, is a common feature in hydrothermal systems (Marchev et al., 2004; Marinova et al., 2014). Interesting in such optic is the presence of an 2-3 m large extensive quartz dyke in the Hooggenoeg Formation just below the Buck Reef Chert outcrop (Fig. 3.19a,b) which unfortunately cannot be traced completely, disappearing before the contact with the basal BRC facies.

The only autochthonous CM microtexture observed in the granular carbonaceous chert, or better, in the associated botryoidal quartz-filled cavity, is the carbonaceous network draping the colloform precipitate on top of the sandy carbonaceous material. Such structures retain morphologies indicative of an originally plastic and cohesive behaviour. They consist of an anastomosing network of carbonaceous material that differs in texture from carbonaceous infillings found interleaved between chert grains in the black massive chert for which also an hydrothermal influence has been proposed. Furthermore the carbonaceous network in the botryoidal vein is bearing oriented quartz rounded grains suggesting a binding and trapping behaviour similar to that observed in modern microbial mats in siliciclastic environments (Eriksonn et al., 2007; Noffke, 2010). All those features are consistent with an interpretation of the carbonaceous network as the remains of an original microbial community rather than remobilized CM along crystals boundaries. Similar structures have been previously observed, in different context, in the BRC and identified as possible microbial mats (Tice and Lowe, 2006). Although bizarre a trapping and binding behaviour would be functional in such sub-surface environment, securing the mats against fluids circulating within

the veins. The presence of a possible microbial mat community in a subsurface hydrothermal environment is consistent with the theory of subsurface chemotrophic niches that has been proposed for the early evolution of life and will be further discussed in the next chapters.



Figure 3.15 – Granular carbonaceous chert and stratiform botryoidal veins. a) Sample C7 (857.19-857.06 m) is a thick granular carbonaceous chert layer (gc) associated to an overlying botryoidal quartz-filled stratiform vein (sbv). It consist of a poorly sorted mixture of abundant sandy carbonaceous grains, but it is possible to observe as well white-grey quartz rounded sandy grains (arrows) and even a large carbonaceous clast or pebble on top of the granular material (dashed red line). The colloform precipitate extend towards the cavity interior. Here the recurrent way-up succession of crinkly laminated chert (clc)-granular carbonaceous chert (gc)-botryoidal vein (sbv)-white bedded chert (wc) can be observed, although the ferruginous chert (clc) at the base of the pattern is composed of just a few microbands. Scale bar: 1 cm. b) Two thin section obtained from sample C7 are used to retrace the relations between the different facies. The ferruginous microbands (clc) are evident and a rip-up clast of crinkly laminated chert (gc) is poorly sorted. At the top of the granular material a chert colloform banding (black arrows) grade towards coarse megaquartz crystals. Scale bar: 600 µm.

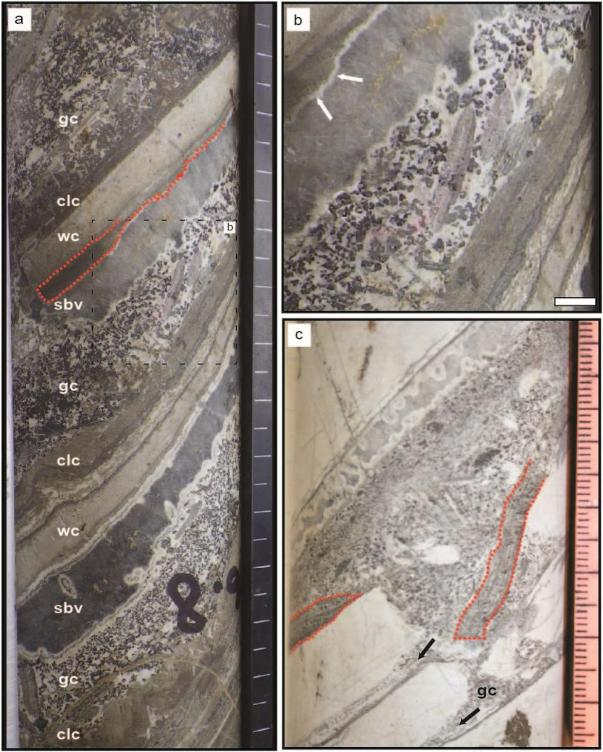


Figure 3.16 – Granular carbonaceous chert and stratiform botryoidal veins. a) In this sample from the lower part of the BARB3 core the recurrent way-up pattern composed by the superimposition of crinkly laminated chert (clc)-granular carbonaceous chert (gc)- stratiform botryoidal vein (sbv)-white bedded chert (wc), is beautifully preserved as two veins occur (and a third is just capping the granular chert seen at the top of the sample). Note that the upper botryoidal stratiform vein is characterized by an irregular contact with the capping white chert bands whereas the latter present hanging fragments of crinkly laminated ferruginous chert (red dashed line). Such fragments are related to the ferruginous bands seen below the underlying granular carbonaceous chert, suggesting the ferruginous chert and the white chert band once were in a conformable, direct, contact. This suggest a brecciation occurred and the granular chert originated afterwards as a cavity filling phase. Ruler for scale, unit: 5 mm. b) The nset in (a) is enlarged. Two very interesting features here are the imbricate structure showed by some rip-up ferruginous clasts and again the crinkly laminated chert hanging from the vein (continue)

roof (white arrows). c) Sample C6 (800-799.82 m) show a tensile failure of the early lithified white chert bands while at the same time the disrupted crinkly ferruginous chert (red dashed lines) bend down plastically into the formed void, while the granular material (gc) fills it. Such fracturing associated with the granular chert and botryoidal vein is here interpreted as caused by overpressure due to hydrothermal fluid, however tectonic processes could as well be involved. Note how the granular material makes is way also at the interface between different white chert bands (black arrows). Brittle fragments detached from the white chert bands take part to the granular material and they can be possibly mobilized within the flux becoming rounded. The granular chert appear to have been deposited in consecutive pulses, as it is suggested by its laminated texture. Ruler on the right, unit is 1 mm.

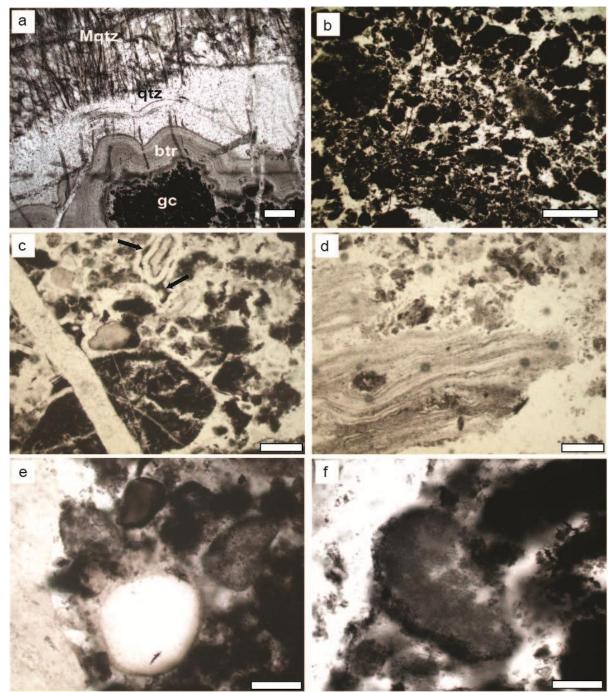


Figure 3.17 – Granular carbonaceous chert include grains of different morphologies, size and origin, mainly sandy carbonaceous grains. a) Botryoidal bending (btr) at the interface between the granular carbonaceous chert (gc) and the quartz filled cavity. Note the transition between the chert colloform precipitate to quartz (qtz) and megaquartz (Mqtz) up in the figure. Scale bar: 1 mm b) Sandy carbonaceous material is composed of simple fluffy CM grains but also composite grains and larger aggregates or clasts. Scale bar: 1 mm c) Spherulitic precipitation associated to rims of dense CM (black arrows) occur around the granular material. Scale bar: 200 μ m d) A rip-up fragment of crinkly laminated chert bears evidence for CM mat-like laminae draping around a carbonaceous grain. Scale bar: 200 μ m e) Other than CM-rich fluffy grains, clots and aggregates, silica grains occur. Those may be extremely rounded like the one in this picture. Many rounded grains derive probably from the reworking and mechanical frictioning on white chert bands brecciated fragments. Scale bar: 600 μ m f) In the lower part of the granular chert layers, close to the underlying ferruginous chert, CM-siderite composite grains occur. Scale bar: 100 μ m.

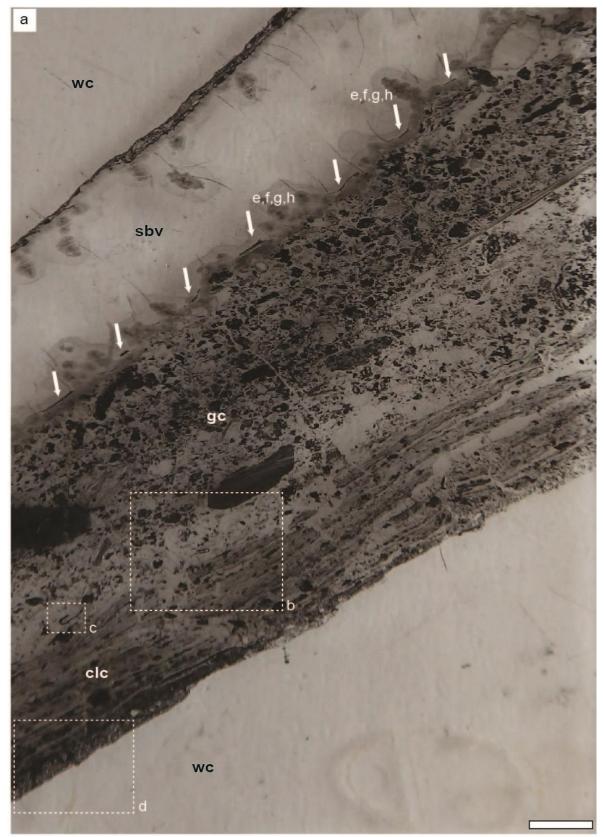


Figure 3.18 – a) Thin section C6D bears evidence for two CM-rich possible microbial structures in the form of mat-like laminae and networks. Note how the lower part of the granular chert is composed of crinkly laminated deformed ferruginous microbands which have been uplifted and disrupted. The more sandy granular component up in the detrital facies has been probably deposited following multiple events as suggest by a laminated texture of the granular facies. Insets are shown in the second part of the figure (b,c,d). Arrows show the site at which, within the stratiform vein the carbonaceous network is commonly observed. Scale bar: 2 mm (...continue).

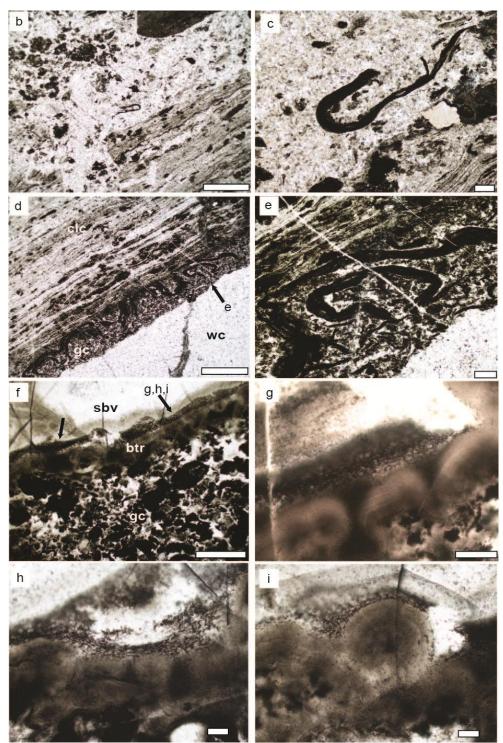


Figure 3.18 (continue) – b) A rip-up mat—like lamination at the base of the granular chert has been folded over. Scale bar: 1 mm c) An other rip-up mat show clearly a plastic cohesive behaviour and it represent a laminae-set, thus the remains of mats consturctor preserved in the crinkly laminated ferruginous chert. Scale bar: μ m. d) Fluidization of the sediments togheter with co-occuring microbands up-lifting have resulted into plastic intrusion between the deformed crinkly ferruginous microbands ant the underlying white chert. Intruded material is rich in mats-like structures consisting of plastic, folded carbonaceous laminae-sets. Scale bar: 1000 μ m. e) Carbonaceous laminae-sets observed in (d). Scale bar: 100 μ m, f) The carbonaceous rich network sits on top of the colloform precipitation and form thicknesses of a few hundred microns. Scale bar: 1 mm. g) CM-rich networks appear to actively trap quartz rounded grains as those are also preferentially oriented planarly to the bedding plane. Scale bar: 1 mm, h) Detail on the CM network, it drapes gently the underlying botryoidal lamination and appear to have a plastic cohesive behaviour draping around protruding colloform precipitates (i). Scale bar: 100 μ m for both pics.

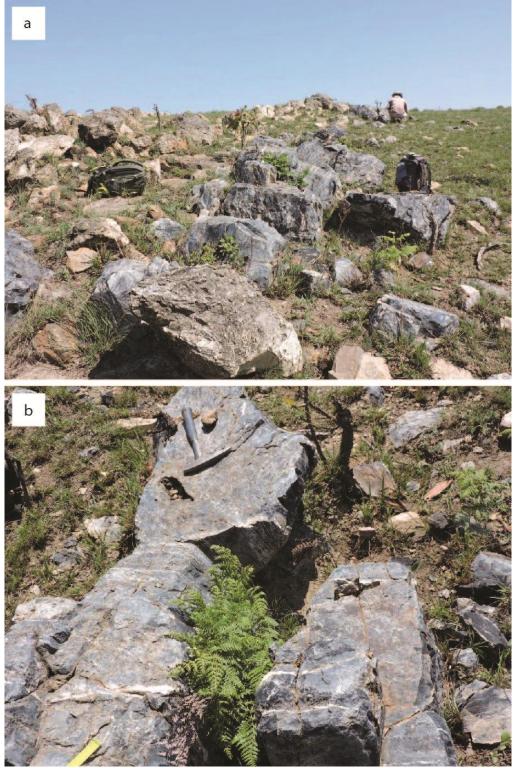


Figure 3.19 – a) An about 2-3 m wide extensive quartz dyke (dusky-grey boulders on the right) in the Hooggenoeg Formation occur just below the Buck Reef Chert outcrop. The dyke can be traced for about 300 m cutting through the Hooggenoeg dacite (grey-brown boulders on the left). Unfortunately the outcrop disappear just before the contact with the basal section of the BRC so that the path and fate of the dike can't be further traced. The picture is taken standing in the Hooggenoeg dacite and it is directed towards the stratigraphic-down so the BRC starts virtually some tens of meters behind the observer. Scale: 20 liters backpacks and Axel Hofmann in the background dressed like a dacite boulder. b) A closer look at the dyke boulders. Scale: hammer

Table. 3.1 – Summary of the BARB3 shallow-platformal core investigation and minero-petrographic results

facies	texture	mineralogy	botryoidal quartz	detrital grains	CM microtextures	CM microtexture proposed origin	proposed depositional setting			
	planar crinkly	abundant	in fenestrae and		laminae	in situ microbial mats remains	low energy benthic equatic			
	laminated	siderite, scattered	stratiform cavities	detrital CM-grains	simple grains	microbial debris				
clc	texture, superposed	pyrite, scarce Co, Ni, Cu, Zn, As- sulphides, sparse	(a few mm thick), around rip-up CM-	and rip-up CM- laminae in fluid-	bitumen-like	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	mat-constructing microbial communities, possible			
	microbands (~1 mm-thick)	chamosite and rare calcite	grains in fluid- intruded bands	uid- intruded bands		microbial debris or abiotic hydrothermal	diffuse silica-rich hydrothermalism			
		frequent pyrite			cloudy grains	microbial debris or abiotic hydrothermal				
h.a	structureless stratiform	and acicular chamosite and	no botryoidal quartz recognized	sparse tabular and	dense interstitial	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	 setting low-energy benthic aquatic environment dominated by mat-constructing microbial communities, possible diffuse silica-rich hydrothermalism CM-rich stratiform hydrothermal vein; seafloor deposit heavily influenced by hydrothermal activity low-energy benthic acquatic environment dominated by precipitation of CM out of the water column after planctonic communities and/or CM-rich exhalative fluids 			
mbc	mesobands (~5 cm-thick), thick stylolites seams	As,Co,Ni- sulphides, rare	during this investigation	angular fragments filled with chert	bitumen-like	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis				
	5	TiO2			cloudy diffuse	microbial debris or abiotic hydrothermal	-			
	ulan on la minata d				simple grains	microbial debris or abiotic hydrothermal				
	planar laminated texture,	scarce pyrite and	rims of botryoidal	no clear derital	wisps	microbial debris or abiotic hydrothermal	precipitation of CM out of			
lbc	superposed microbands (a	finely grained chamosite	precipitate around CM-grains	grain recognized	composite grains	microbial debris or abiotic hydrothermal	 environment dominated by mat-constructing microbial communities, possible diffuse silica-rich hydrothermalism CM-rich stratiform hydrothermal vein; seafloor deposit heavily influenced by hydrothermal activity low-energy benthic acquatic environment dominated by precipitation of CM out of the water column after planctonic communities and/or CM-rich exhalative fluids subsurface environment resulting from the interaction between pervading silca-rich hydrothermal fluids and soft sediments, possible subsurface mat-forming 			
	few mm thick)				dense interstitial	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis				
					network	in situ microbial mats remains	aubaurfage anvironment			
			within ubiquitous	detrital CM-rich	laminae	microbial mats (detrital material derived from the clc facies)	resulting from the			
Gc	sandy, planar laminations, associated to sbv	rare siderite and chamosite	large sby, rims around the sandy grains	grains, rip-up fragments from the clc	CM-rich grains	microbial debris (detrital material derived from the clc facies)	hydrothermal fluids and soft sediments, possible			
					dense interstitial	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	e			

Chapter 4

BARB3 carbonaceous matter structure and

nanotexture

4.1 Structural characterization of the BARB3 carbonaceous matter

As observed in the previous chapter, although representing a minor component in the Archaean cherts, CM is widely distributed within the BARB3 shallow-platformal deposits in the form of various microtextures (Tab. 3.1). These can be facies specific or may occur in a similar form across the different facies. For instance, while mat-like carbonaceous laminae preserved *in situ* are specific to the crinkly laminated chert, CM clotted textures occur analogously in the ferruginous microbands, in the laminated black chert and possibly, although poorly preserved, in the massive black chert. In other cases, like for the massive black chert, the overall CM assemblage is so peculiar that it represents a discriminating factor by which the facies can be distinguished. Finally the granular carbonaceous chert consists of a mixture of allochthonous microtextures derived from other primary deposits, mainly the crinkly laminated chert. However the granular carbonaceous chert also bears a peculiar carbonaceous network that caps the colloform quartz precipitate immediately overlying the sandy carbonaceous material and that is not observed in the other BARB3 facies.

The between-facies divergences and affinities in the CM microtextural assemblage advocate for exclusive and shared pathways in the CM cycle, implying segregated and overlapping depositional conditions or interactions, apparently mediated by circulating fluids, between the different lithofacies CM. To further explore the BARB3 CM possible sources and evolution and to support or reject proposed environmental settings, the chemical structure of such carbonaceous microtextures is here investigated by means of Raman microspectroscopy. The CM microtextures analyzed are summarized in Tab. 4.1 and Fig. 4.1. As reported already in the method section (Chapter 2) for each thin section a number of at least 25 collected spectra has been used in the calculations to take into account the within-sample CM structural variability (Aoya et a., 2010). The so obtained dataset is thus truly reflective of the average CM structural characteristic for each sample so that a between-sample heterogeneity can be investigated. Spectra have been collected so to cover most of the thin section volume homogeneously like showed in Fig.4.2.

Table. 4.1 –CM microtextures analyzed through Raman microspectroscopy during this study. The depositional set is again reported. Each microtexture is visualized in the following Fig. 4.1

facies	proposed depositional setting	CM analyzed microtextures	CM microtexture proposed origin	analyzed sample
		mat-like laminae (Fig.4.1a)	microbial mats remains preserved in situ	D11A, C3A
clc	low-energy benthic aquatic environment dominated by mat-constructing microbial communities, possible diffuse silica-rich hydrothermalism	simple grains (Fig. 4.1b)	microbial debris	D11A, C3A
	-	bitumen-like (Fig. 4.1c)	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	D1
		cloudy grains (Fig. 4.1e)	microbial debris or abiotic hydrothermal CM	C9E
mbc	CM-rich stratiform hydrothermal vein; seafloor deposit heavily influenced by hydrothermal activity	dense interstitial (Fig. 4.1d)	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	C9E
mbe		bitumen-like (Fig. 4.1c)	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	C9E
		cloudy diffuse (Fig. 4.1e)	microbial debris or abiotic hydrothermal CM	C9E
lbc	low-energy benthic acquatic environment dominated by precipitation of CM out of the water column after	simple grains (Fig. 4.1f)	microbial debris or abiotic hydrothermal CM	C2C
100	planctonic communities and/or CM-rich exhalative fluids	bitumen-like XcV (Fig. 4.1g)	hydrocarbon rich fluid after abiotic hydrothermal CM or biotic OM diagenesis	C2C
	subsurface environment resulting from the interaction between pervading silca-rich	mat-like network (Fig. 4.1h)	microbial mats remains preserved in situ	D4A
gc	hydrothermal fluids and soft sediments, possible subsurface mat-forming communities	CM-rich grains (Fig. 4.1h)	microbial debris (detrital material derived from the clc facies)	D4A

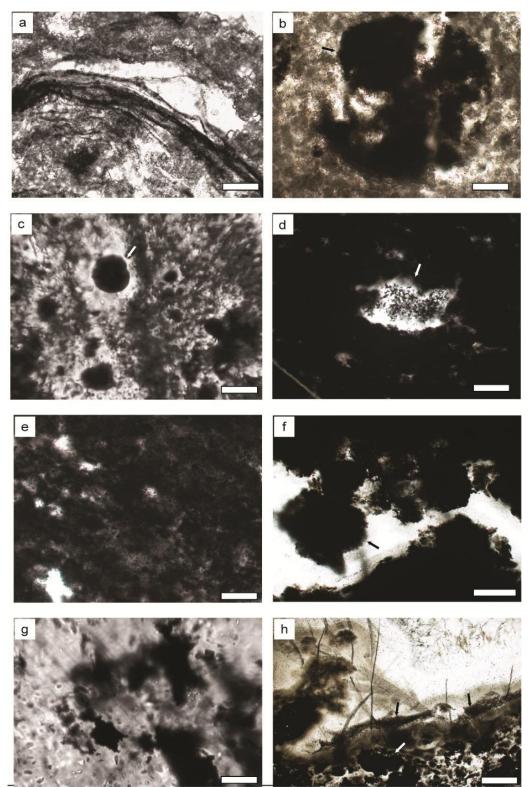


Figure 4.1 – CM microtextures characterized by Raman spectroscopy. a)Mat-like carbonaceous laminae and lamina-sets occurring in the crinkly laminated ferruginous chert. Scale bar: 100 μ m. b) Simple carbonaceous grains occurring in the crinkly laminated chert. Scale bar: 50 μ m. c) Bitumen-like spheres and blobs occurring mainly within the massive black chert, but also in the crinkly laminated chert sample D1. Scale bar: 50 μ m. d) Interstitial carbonaceous material occurring in the massive black chert. Scale bar: 100 μ m. e) Diffuse cloudy CM of the massive black chet. Scale bar: 200 μ m. f) Simple carbonaceous grains within laminated black chert. Scale bar: 100 μ m. g) Bituminous CM within cross-cutting veins analyzed within the laminated black facies. Scale bar: 20 μ m. h) Simple carbonaceous grains (white arrow) and mat-like carbonaceous network (black arrows) within the granular carbonaceous chert. Scale bar: 200 μ m.

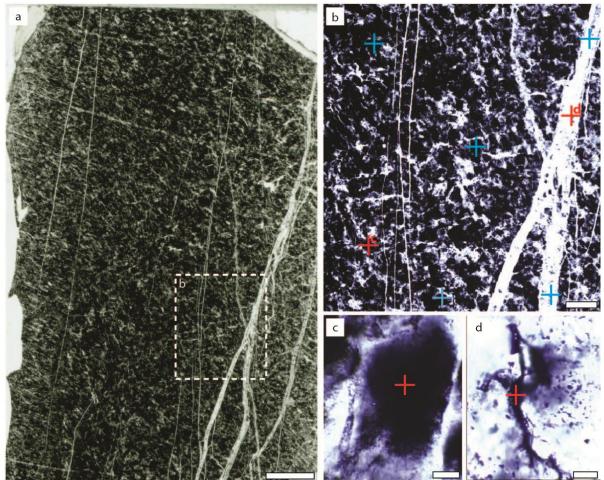


Figure 4.2 – This figure exemplify how Raman spectra have been collected on the thin sections for this specific CM microtextures structural characterization. a) Thin section C2C is representative of the laminated black chert. As reported in Tab. 4.1 for this carbonaceous rich chert the analyzed microtextures are: CM simple grains (c) and bitumen-like CM (d) observed within the cross-cutting veinlets (XcV). Spectra have been collected throughout the whole thin section. Several areas of the section have been characterized like for inset (b). Here each collected spectra (red and blue crosses) is representative of a discrete CM microtexture, like visualized by the red crosses (c) and (d) and respective microtextures (figures c and d), meaning that to each spectra correspond an individual grain or a discrete bitumen-like microtexture. Out of all the spectra collected the ones having the best resolution and thus resulting in the more accurate fit have been used in the calculation starting from a minimal number of 25 spectra per section. The approach has been the same for all the thin sections microtextures except for the crinkly laminated chert whereas each individual CM lamina-set has been analyzed by multiple regularly spaced spectra. Scales are: a) 3 mm; b) 500 μ m; c and d) 20 μ m.

4.1.1 General characteristics of the BARB3 CM

Spectral characteristics of the analyzed CM are consistent throughout the whole data-set so that Raman results, at first glance, appear very homogeneous (Fig. 4.3). All spectral profiles are characterized in the first-order by a well-developed D peak having a weak down-shifted shoulder (D4 band) and a less intense G band including an up-shifted shoulder (D2 band). A further Raman shift arises in between D and G (D3 band) that occurs closer to the graphitic band base producing a slightly asymmetric aspect. In the second-order range, three weak broad signals appear at about 2690 cm⁻¹, 2950 cm⁻¹ and 3220 cm⁻¹, respectively. This

overall spectral pattern is similar to that from disordered CM in meta-sediments subjected to a greenschist facies metamorphic grade (chlorite zone; e.g., Yui et al., 1996). The spectra similarities are especially evident when comparing CM belonging to the crinkly laminated chert, laminated black chert and granular carbonaceous chert. Between the facies there is a minor difference is observed in the CM from the massive black chert (Fig. 4.3), as this is characterized by a more intense G, D4 and D3 bands together with a slightly wider D1.

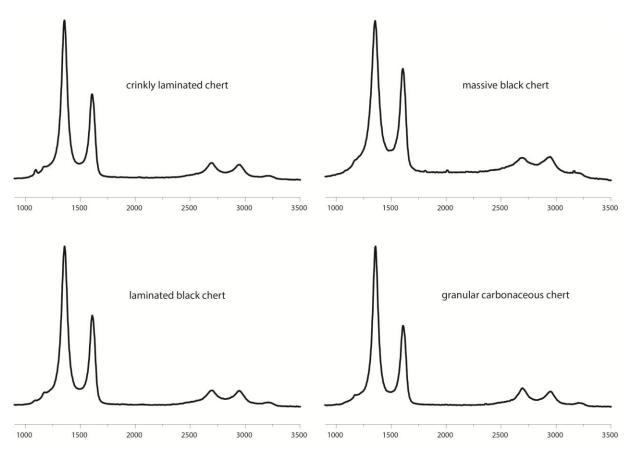


Figure 4.3 – Comparison of the average Raman signal obtained by the sum of all spectra reported in S2 for each BARB3 facies (at least 25 spectra par facies). All the spectra show a striking similarity in their profile, nevertheless the massive black chert has a higher G intensity as well as more developed D3 and D4 bands.

Out of several possible fitting models a five-curves deconvolution protocol, such as that proposed by Sadezky et al. (2005), best fits the analyzed BARB3 CM resulting in the highest adjusted- R^2 values (which in Origin represent the parameter estimating the fitting accuracy whereas the perfect fitting result in adjusted- R^2 = 10). The first-order carbonaceous spectra are thus decomposed into four Lorentzian at about 1199 cm⁻¹ (D4), 1355 cm⁻¹ (D1), 1604 cm⁻¹ (G), 1626 cm⁻¹ (D2) and a Gaussian at ~1544 cm⁻¹ (D3). The most significant bands parameters and calculated ratios obtained after spectra deconvolution are here reported as average values by sample (Tab. 4.2), by facies (Tab. 4.3) and by carbonaceous microtexture

(Tab. 4.4). Parameters and ratios for each decomposed spectra can be found in the supplementary material (Supplementary material S2).

Kouketsu et al. (2014) proposed a five-curves fitting (called Fitting E), similar to the one used here, as the most appropriate for sedimentary CM that experienced peak metamorphic temperatures ranging between 300 and 340°C. In agreement with such evidence and with the overall spectral similarity to CM subjected to greenschist facies metamorphism (Yui et al., 1996) we used two CM Raman geothermometers calibrated for low-metamorphic rocks. The first, proposed by Beyssac et al. (2002), works best at temperatures ranging between 330 and 650 °C and relies on the ratio R_2 (1) and its relation with temperature expressed in (2).

$$R_2 = A_{D1} / (A_{D1} + A_{D2} + A_G)$$
(1)

with

$$T = -445 * R_2 + 641 (\pm 50^{\circ}C)$$
(2)

The second, proposed by Kouketsu et al. (2014), works for temperatures ranging between 150 and 400 °C and consists of two possible equations (3), (4) in which the metamorphic temperature is correlated to the full-width at half maximum intensity (FWHM) of D1 and D2.

$$T (^{\circ}C) = -2.15 (FWHM-D1) + 478 (\pm 30^{\circ}C)$$
(3)

and

$$T (^{\circ}C) = -6.78 (FWHM-D2) + 535 (\pm 50^{\circ}C)$$
(4)

Average temperatures calculated for the whole dataset correspond to 326 ± 50 °C (2), 337 ± 50 °C (3) and 361 ± 50 °C (4) respectively. The three Raman geothermometers (Beyssac et al., 2002, Kouketsu et al., 2014) show a metamorphic imprint that falls within the lower greenschist metamorphic temperature range (Tab. 4.2, 4.3, 4.4 and S2), coherently with the thermal history of the Onverwacht Group (Tice et al., 2004).

Several characteristics of all the fitted spectra including (i) the regular presence of well developed D3 and D4 bands, (ii) the prevailing D1 intensity on G, (iii) the D1 width range FWHM_{D1}= \sim 53-93 cm⁻¹ (\sim 65 cm⁻¹ on average) and (iv) the I_D/I_G range R₁= 1.36-2.62 (2.07 in average) are consistent with poorly ordered CM typical of low-greenschist Archaean meta-

sediments (Delarue et al., 2016; Sforna et al., 2014). All the analyzed material fits well with the Archaean carbonization continuum proposed by Delarue et al., (2016), as the BARB3 material situates at high R1 values (Fig. 4.4), almost at the limits of the carbonization/graphitization continuum, consistent with previously analyzed CM from the Kromberg and Hooggenoeg formations (Delarue et al., 2016; Hofmann et al., 2013). The BARB3 CM thus appears to consists of very poorly organized (developed D4) stacks of nanometric, polyaromatic, graphene-like layers characterized by out of plane defects (D3) (Beyssac et al., 2003), corresponding to a carbonaceous structural grade which reached the end phases of the carbonization process (Charon et al., 2014; Delarue et al., 2016).

All investigated CM has a geothermal imprint and a crystallinity level that is consistent with the degree of organization usually found in CM from Archaean terrains of comparable metamorphic grade (Delarue et al., 2016; Marshall et al., 2007; Sforna et al., 2014) confirming the BARB3 CM Archaean authenticity.

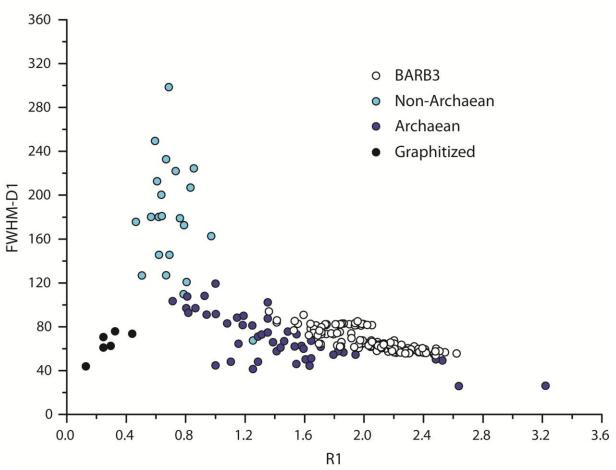


Figure 4.4 – Compilation of R1 ratio and FWHM-D1 representing the Raman-derived carbonization continuum showing evolution of Archaean and Non-Archaean CM with structural disorder. Modified from Delarue et al., 2016.

Table 4.2 – Raman parameters and ratios calculated by sample
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Sample	Facies	ω_{D1}	Γ_{D1}	ω _G	Γ _G	R_1	Γ _{D1/G}	I _{D1} /(I _{D1} +I _G)	A _{D1} /A _G	R ₂ (1)	ΔT C° (3)	R _{D3} (5)	R _{D4} (6)
D11A	Crinkly laminated chert	1355,48	60,04	1603,57	43,89	2,19	1,37	0,69	3,01	0,70	349,92	0,05	0,05
	σ	0,24	3,05	1,16	2,03	0,16	0,10	0,02	0,28	0,01	6,55	0,01	0,00
C3A	Crinkly laminated chert	1356,66	60,52	1604,23	44,20	2,23	1,37	0,69	3,05	0,71	348,89	0,06	0,05
	σ	0,70	4,31	1,04	1,41	0,20	0,10	0,02	0,21	0,01	9,27	0,01	0,01
D1	Crinkly laminated chert	1354,05	80,59	1603,98	42,26	1,85	1,91	0,65	3,50	0,72	305,73	0,10	0,07
	σ	0,55	4,12	0,99	2,46	0,15	0,16	0,02	0,46	0,02	8,85	0,01	0,01
C9E	Massive black chert	1354,01	74,55	1603,83	46,02	1,72	1,63	0,63	2,79	0,69	318,72	0,08	0,07
	σ	1,55	8,96	1,72	4,18	0,14	0,20	0,02	0,39	0,02	19,26	0,02	0,01
C2C	Laminated black chert	1356,52	62,73	1605,37	42,00	2,14	1,49	0,68	3,16	0,71	344,13	0,06	0,06
	σ	0,57	7,11	0,84	1,79	0,26	0,13	0,03	0,26	0,01	15,28	0,01	0,01
D4A	Granular carbonaceous chert	1356,61	60,08	1604,64	42,74	2,23	1,41	0,69	3,13	0,71	349,83	0,05	0,05
	σ	0,46	4,82	0,61	1,33	0,18	0,11	0,02	0,19	0,01	10,35	0,01	0,01

Facies	ω_{D1}	Γ_{D1}	ω_{G}	Γ _G	R_1	Γ _{D1/G}	$I_{D1}/(I_{D1}+I_G)$	A _{D1} /A _G	R ₂ (1)	ΔT C° (3)	R _{D3} (5)	R _{D4} (6)
Crinkly laminated chert (all)	1355,40	66,85	1603,92	43,46	2,09	1,55	0,6747	3,18	0,7112	335,27	0,0662	0,0640
σ	1,18	10,30	1,09	2,16	0,24	0,28	0,0261	0,40	0,0145	22,15	0,0227	0,0285
Mats-Grains	1356,05	60,27	1603,89	44,04	2,21	1,37	0,6874	3,03	0,7051	349,43	0,0521	0,0590
σ	0,79	3,67	1,14	1,75	0,18	0,10	0,0180	0,25	0,0071	7,90	0,0082	0,0335
Bitumen-like	1354,05	80,59	1603,98	42,26	1,85	1,91	0,6482	3,50	0,7239	305,73	0,0956	0,0744
σ	0,55	4,12	0,99	2,46	0,15	0,16	0,0196	0,46	0,0176	8,85	0,0126	0,0053
Massive black chert	1354,01	74,55	1603,83	46,02	1,72	1,63	0,6320	2,79	0,6930	318,72	0,0801	0,0716
σ	1,55	8,96	1,72	4,18	0,14	0,20	0,0200	0,39	0,0205	19,26	0,0173	0,0080
Laminated black chert (all)	1356,52	62,73	1605,37	42,00	2,14	1,49	0,6788	3,16	0,7108	344,13	0,0601	0,0572
σ	0,57	7,11	0,84	1,79	0,26	0,13	0,0303	0,26	0,0093	15,28	0,0146	0,0099
Grains	1356,69	60,46	1605,24	41,62	2,22	1,45	0,6886	3,22	0,7132	349,02	0,0553	0,0541
σ	0,33	3,15	0,74	1,40	0,13	0,08	0,0127	0,20	0,0061	6,76	0,0065	0,0045
Bitumen-like XcV	1355,25	79,41	1606,31	44,84	1,55	1,77	0,6067	2,71	0,6937	308,28	0,0953	0,0799
σ	0,16	5,32	1,15	2,02	0,14	0,08	0,0220	0,26	0,0116	11,43	0,0008	0,0090
Granular carbonaceous chert	1356,61	60,08	1604,64	42,74	2,23	1,41	0,6896	3,13	0,7084	349,83	0,0539	0,0532
σ	0,46	4,82	0,61	1,33	0,18	0,11	0,0172	0,19	0,0071	10,35	0,0085	0,0058

Table 4.3 – Raman parameters and ratios calculated by facies. Crinkly laminated chert is further calculated excluding the bitumen-like sphere. Laminated black chert is calculated excluding the bitumen-like CM from cross-cutting veins.

CM microtexture	Facies	Sample	ω_{D1}	Γ_{D1}	ω_{G}	Γ _G	R1	Γ _{D1/G}	I _{D1} /(I _{D1} +I _G)	A _{D1} /A _G	R ₂ (1)	ΔT C° (3)	R _{D3} (5)	R _{D4} (6)
Mat-like laminae	Clc	D11A	1355,57	57,81	1603,12	44,42	2,28	1,30	0,6944	2,98	0,7023	354,70	0,0456	0,0522
		σ	0,26	1,71	0,77	1,96	0,12	0,06	0,0107	0,25	0,0070	3,68	0,0063	0,0045
Grain	Clc	D11A	1355,37	62,45	1604,06	43,31	2,09	1,44	0,6760	3,03	0,7061	344,74	0,0533	0,0570
		σ	0,16	2,20	1,34	2,02	0,15	0,07	0,0160	0,32	0,0078	4,73	0,0056	0,0043
Mat-like laminae	Clc	C3A	1356,75	58,09	1603,77	44,25	2,33	1,31	0,6996	3,08	0,7066	354,10	0,0515	0,0504
		σ	0,78	1,61	0,85	1,66	0,13	0,05	0,0116	0,24	0,0078	3,47	0,0057	0,0043
Grain	Clc	C3A	1356,47	66,06	1605,30	44,07	2,00	1,50	0,6664	2,99	0,7054	336,97	0,0634	0,0622
		σ	0,48	3,19	0,51	0,60	0,12	0,06	0,0144	0,09	0,0026	6,87	0,0081	0,0047
Bitumen-like	Clc	D1	1354,05	80,59	1603,98	42,26	1,85	1,91	0,6482	3,50	0,7239	305,73	0,0956	0,0744
		σ	0,55	4,12	0,99	2,46	0,15	0,16	0,0196	0,46	0,0176	8,85	0,0126	0,0053
Bitumen-like	Mbc	C9E	1353,47	79,75	1603,59	46,07	1,67	1,74	0,6250	2,89	0,6990	307 <i>,</i> 55	0,0889	0,0722
		σ	1,65	6,96	2,06	4,89	0,15	0,13	0,0208	0,41	0,0202	14,96	0,0153	0,0087
Interstitial	Mbc	C9E	1354,48	72,06	1604,21	43,21	1,77	1,67	0,6390	2,94	0,6970	324,08	0,0776	0,0679
		σ	1,18	2,82	1,41	1,41	0,12	0,06	0,0158	0,22	0,0010	6,06	0,0064	0,0020
Cloudy	Mbc	C9E	1355,02	63,66	1604,20	47,29	1,82	1,35	0,6448	2,47	0,6769	342,13	0,0606	0,0719
		σ	0,86	1,60	0,87	2,70	0,10	0,08	0,0128	0,26	0,0191	3,44	0,0046	0,0087
Grain	Lbc	C2C	1356,69	60,46	1605,24	41,62	2,22	1,45	0,6886	3,22	0,7132	349,02	0,0553	0,0541
		σ	0,33	3,15	0,74	1,40	0,13	0,08	0,0127	0,20	0,0061	6,76	0,0065	0,0045
Bituminous-XcV	Lbc	C2C	1355,25	79,41	1606,31	44,84	1,55	1,77	0,6067	2,71	0,6937	308,28	0,0953	0,0799
		σ	0,16	5,32	1,15	2,02	0,14	0,08	0,0220	0,26	0,0116	11,43	0,0008	0,0090
Mat-like network	Gcc	D4A	1356,88	56,24	1604,74	42,61	2,34	1,32	0,7003	3,11	0,7079	358,08	0,0485	0,0489
		σ	0,24	1,05	0,59	1,06	0,11	0,04	0,0104	0,18	0,0078	2,26	0,0045	0,0019
Grain	Gcc	D4A	1356,34	63,92	1604,53	42,87	2,12	1,49	0,6789	3,15	0,7089	341,58	0,0592	0,0575
		σ	0,47	3,92	0,63	1,58	0,16	0,10	0,0160	0,21	0,0067	8,42	0,0083	0,0051
Mat-like			1356,45	57,38	1603,91	43,74	2,32	1,31	0,6983	3,06	0,7058	355,64	0,0488	0,0504
σ			0,76	1,67	0,98	1,76	0,12	0,05	0,0110	0,23	0,0078	3,59	0,0059	0,0039
Grains - Cloudy			1356,16	62,62	1604,75	43,08	2,11	1,46	0,6770	3,07	0,7064	344,36	0,0573	0,0606
σ			0,74	3,55	0,97	2,29	0,18	0,09	0,0189	0,31	0,0130	7,63	0,0074	0,0070
Bituminous - Interstitial			1353,98	79,64	1604,03	43,75	1,77	1,83	0,6371	3,21	0,7118	307,78	0,0921	0,0736
	σ	1,14	5,49	1,56	3,74	0,17	0,17	0,0235	0,52	0,0217	11,81	0,0135	0,0070	

Table 4.4 – Raman parameters and ratios calculated by microtexture. Crinkly laminated chert (clc), massive black chert (mbc), laminated black chert (lbc), granular carbonaceous chert (gcc).

4.1.2 BARB3 CM structural heterogeneity

Although all the Raman spectra collected during this study show a striking similarity in their profiles, some structural differences in the CM do occur and is apparent by slight changes in the relative intensity and width of select peaks (Fig. 4.3). Such changes can be better resolved by a comparison between parameters and ratios calculated after deconvolution. Particularly, it has been shown that for the low-greenschist range of metamorphic conditions a combination of FWHM_G, R_1 (I_{D1}/I_G) and $I_{D1}/I_{D1}+I_G$, rather than just R_1 , which alone becomes unreliable for this grade of CM maturation (Ferrari and Robertson, 2000). This combination of ratios is a good proxy for variations in CM maturity, with FWHM_G decreasing and R₁ and $I_{D1}/I_{D1}+I_G$ increasing with increasing order (Jehlička et al., 2003; Allwood et al., 2006). Ratios including A_{D1}/A_G , R_{D3} (I_{D4}/I_{D1}) and R_{D4} (I_{D3}/I_{D1}), together with R_1 and R_2 allows the heterogeneity in the BARB3 CM type of maturation to be estimated (Yui et al., 1996; Beyssac et al., 2003; Sforna et al., 2014; Delarue et al., 2016). Similar results can be observed also for $FWHM_D$ and $FWHM_D/FWHM_G$ against R₁, whereas the variation of peak widths as a function of the R₁ ratio is sensitive to variations in the structure of poorly organized CM of the type found in Archean rocks (Sforna et al., 2014; Delarue et al., 2016). Combinations of such parameters and ratios can be used to fully appreciate CM heterogeneities.

Here, possible structural differences in the BARB3 CM are tested through three consecutive steps in order to explore the carbonaceous heterogeneity between samples, between facies and finally between microtextures. To do so, ratios and parameters described above have been used together with $FWHM_{D1/G}$ -vs-R₁ and $FWHM_{D1}$ -vs-R₁ plots for sample (Tab. 4.2, Fig. 4.5), facies (Tab. 4.3, Fig. 4.6) and microtexture (Tab. 4.4, Fig. 4.7) levels.

At the sample scale the FWHM_{D1/G}-vs-R₁ plot (Fig. 5.4) is very chaotic and the measurements obtained for each thin section greatly overlap with the only partial exception of D1 and C9E. Those two samples show lower R₁ and higher FWHM_{D1/G} ($\Gamma_{D1/G}$) values together with the highest R_{D3} and R_{D4} (Tab. 4.2). This suggests that D1 and C9E host CM with a lower structural order. However, the CM signal in D1 derives from the bituminous-like blobs that only occur in this crinkly laminated chert sample. C9E instead is representative of the massive black chert with its unique bituminous and interstitial dense textures. Thus the two samples strongly differentiate from the other investigated thin sections in term of microstructure and facies respectively. At the same time other samples belonging to the same facies or including similar microtextures, such as D11A and C3A, greatly overlap, suggesting the absence of a merely between-sample heterogeneity.

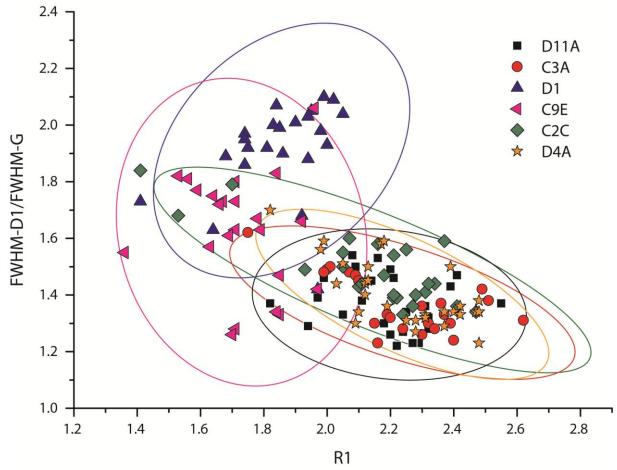


Figure 4.5 – FWHM_{D1/G}-vs-R₁ plot showing between-sample variability. 95% confidence ellipses are marked for each sample.

A better understanding of the BARB3 carbonaceous heterogeneity can be obtained when comparing CM from the different depositional facies (Fig. 4.6). Although the crinkly laminated chert shows a very wide scatter of values, it can be observed that this actually consists of two distinct groups. One group showing higher $\Gamma_{D1/G}$ and lower R₁ values is defined entirely by the bituminous-like CM of the D1 sample which is atypical in the crinkly laminated facies and shows no evidence of primary deposition. A similar reasoning can be presented for the highest $\Gamma_{D1/G}$ and lowest R₁ values observed for the laminated black chert whereas those derived from the measurements taken on the bitumen-like CM found in crosscutting veinlets, which are ubiquitous in the BARB3 and not confined to this depositional facies. In both the crinkly laminated and laminated black chert, when excluding the bituminous CM from parameters and ratios calculations, the facies resulted in values of $\Gamma_{D1/G}$ and R₁ displaying a dramatically reduced standard deviation (Tab. 4.3). Thus, although this suggests a role of the microtexture analyzed, it also highlights that a between-facies heterogeneity may exist. When the bituminous material is excluded, the crinkly laminated

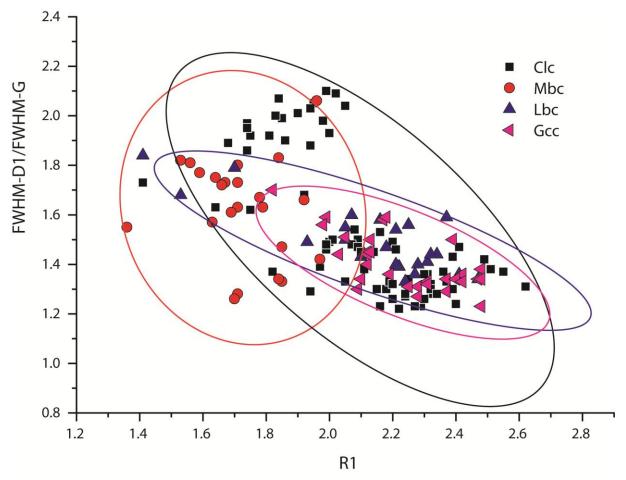


Figure 4.6 – FWHM_{Dl}/_G-vs-R₁ plot showing between-facies variability. 95% confidence ellipses are marked for each facies. Crinkly laminated chert (Clc), Massive black chert (Mbc), Laminated black chert (Lbc); Granular carbonaceous chert (Gcc).

chert, laminated black chert and granular carbonaceous chert group together and with the exception of the black massive chert, most likely reflect depositional differences described in the previous chapter. The peculiarity of the black massive facies suggests a comparison with hydrothermal veins rather than primary sedimentary deposits.

By exploring the possible between-sample and between-facies heterogeneity it has already been suggested that CM microtextures may also have a role in the distribution of parameter and ratio values. As illustrated at the beginning of the chapter the CM microtextures observed in the BARB3 shallow-platformal deposits can be defined as three major entities: bituminous-like or interstitial CM, carbonaceous grains and mat-like structures (laminae and network). It is this categorization, proposed after the core facies interpretation and sample minero-petrographic characterization, that show the best correlation with the range of structural disorder expressed by the analyzed CM. As observed in the FWHM_{D1/G}-vs-R₁ plot (Fig. 4.7), such microtexture outlines three well-defined clusters in the data

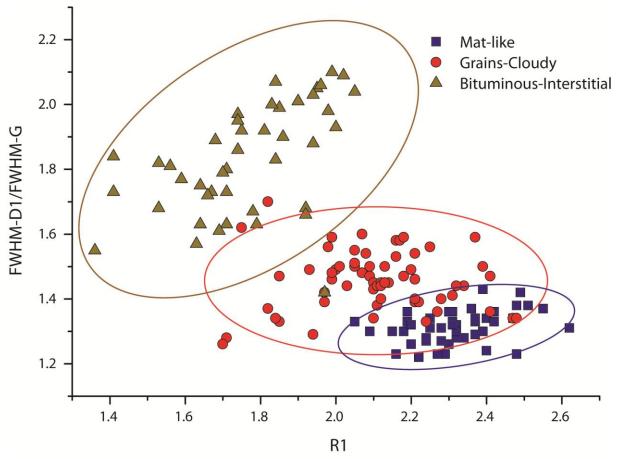


Figure 4.7 – FWHM $_{D1/G}$ -vs- R_1 plot showing between-microtexture variability. 95% confidence ellipses are marked for each CM microtexture.

scattering. Similar results are obtained for the $I_{D1}/I_{D1}+I_G$, A_{D1}/A_G , R_2 , R_{D3} and R_{D4} ratios (Tab. 4.4) and results have low standard deviations indicating a reliable grouping of the microtextures. The three defined clusters consist of: (I) microbial mat-like laminae and carbonaceous network from the crinkly laminated chert and the granular carbonaceous chert (botryoidal vein), respectively; (II) CM-rich individual grains from the crinkly laminated facies, the laminated black chert, the sandy carbonaceous material occurring within the granular chert but also the diffuse cloudy CM forming putative grains within the black massive facies; and (III) CM which is observed as structureless material in the form of smooth spheres, blobs, or as an interstitial, vein filling substance suggesting it was originally part of a fluid carbonaceous morphologies correspond to a different chemical structure and has implications concerning the origin of the BARB CM and the depositional relations between the carbonaceous rich facies.

4.1.3 Possible sources for the BARB3 CM heterogeneity

The degree of order reached by natural CM during its irreversible maturation within meta-sedimentary rocks is reflected by the characteristics of its Raman spectrum and depends mainly on the metamorphic P-T conditions and on the nature of the original carbonaceous precursor (Yui et al., 1996; Beyssac et al., 2002). In light of such correlations Raman spectroscopy has been used to reconstruct the metamorphic history of CM-hosting rocks and to investigate the degree of its structural disorder and heterogeneity (Beyssac et al., 2003; Lahfid et al., 2010; Marshall et al., 2012; Kouketsu et al., 2014). However caution must be taken when investigating the structure of CM through Raman spectroscopy as some steps in the analytical procedures can potentially introduce extrinsic variability. Thus before exploring possible causes for the BARB3 CM heterogeneity some preliminary consideration must be given with regards to the experimental approach.

During this study a low laser power (3 mW) was used focusing only on CM structures embedded in quartz below the thin section surface to avoid sample heating (Everall et al., 1991) and excluding a contribution to CM defect by surface polishing (Beyssac et al., 2003). Due to the anisotropic character of graphite-like materials, in Raman spectroscopy a preferential orientation of the analyzed CM with respect to the incoming laser radiation can result in a structural sampling bias. All discrete CM analyzed during this study consists of concentrations of sub-micron sized particles interweaved between the chert grains showing no preferential orientation in space, as will be illustrated also in the following CM nanotexture section. The overall similarity of all collected spectra allowed the application of a consistent linear baseline correction and the fitting through the same deconvolution model applied with no fixed parameters, leading to highly comparable results (Beyssac et al., 2003; Lünsdorf et al., 2014). The quality of fitting has been evaluated visually and based on the adjusted- R^2 values, which in the Origin software reflects the goodness of the deconvolution; poorly fitted spectra have been excluded from any calculation or discussion. Thus, minimizing and excluding extrinsic inputs, allowing for a reliable reading of CM intrinsic structural heterogeneity.

4.1.3.1 Structural divergence of the massive black chert

When scrutinizing possible sources for the facies and microtextural-related structural heterogeneity observed in the BARB3 CM, it is important to consider, perhaps counter

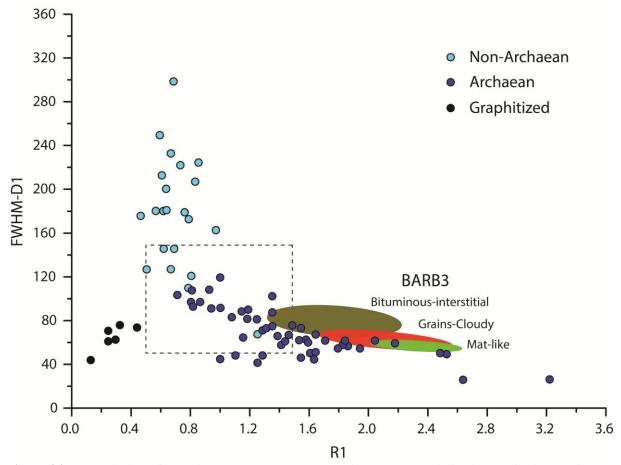


Figure 4.8 – Compilation of R1 ratio and FWHM-D1 representing the Raman-derived carbonization continuum showing evolution of Archaean and Non-Archaean CM with structural disorde. The cluster related to the main three microtexture groups observed in the BARB3 are marked with their respectively 95% confidence ellipses. Modified from Delarue et al., 2016

intuitively, that the exquisitely preserved mat-like laminae, and the carbonaceous network, show the higher grade of structural order when compared to the grains and the structureless bituminous and interstitial CM. This can be observed by superimposing the three clusters (defined by their 95% confidence ellipses, Fig. 4.8) onto the Archaean carbonization continuum developed by Delarue et al. (2016). Furthermore, the carbonaceous grains and mat-like structures greatly overlap so that the structural distinction is greater between those primary microtextures and the structureless CM.

Probably deriving from an originally viscous hydrocarbon phase (Buick, 1990; He et al., 2015; Suárez-Ruiz et al., 2016), bituminous and dense interstitial CM occur mainly in the BARB3 massive black facies. This facies has been here interpreted as either a massive carbonaceous hydrothermal vein or as an hydrothermally influenced deposit. Using equation (3), which is the more accurate in the 200-400 °C range (Kouketsu et al., 2014), it can be seen that, although still falling within the range of error of \pm 50°C, the massive black chert is the facies that dissociates most from the average values, resulting in a temperature of 318 \pm 50°C

(3) (Tab. 4.3). Similar values were obtained from the analysis on the bitumen-like material from sample D1 and from the cross-cutting veinlets (Tab. 4.3). However the massive black facies also includes diffuse cloudy CM that instead has a structural order and geothermal imprint comparable to that of the grains and mat-like structures observed in the other chert facies (Tab. 4.4). Thus the massive black chert, includes at least two categories of carbonaceous microtextures bearing a very diverse structural order.

4.1.3.2 Carbonaceous grains vs carbonaceous mats

CM-rich laminae observed in the crinkly laminated ferruginous chert shows features consistent with fossil and modern benthic microbial mats. Most notably their plastic behaviour, cohesiveness and morphologies produced by the interaction of mats with pervading fluids and gentle currents in low energy aquatic environments (Eriksson et al., 2007; Walsh, 2010; Tice et al., 2011). Morphological evidence suggesting an original plastic and cohesive carbonaceous nature have also been observed in the carbonaceous networks that drapes the colloform precipitate on top of the granular carbonaceous material. Furthermore such CM-rich networks show evidence for possible trapping and binding behaviour, usually observed in modern mats in siliciclastic environments (Eriksonn et al., 2007; Noffke, 2010). The interpretation of those carbonaceous microtextures as possible microbial mats is strengthened by the extremely similar structural order of their constitutive CM as shown by Raman analyses (Tab. 4.4). The analyzed structures, other than bearing exquisitely preserved mat-like morphologies, come from different depth along the core, yet show an almost perfect overlapping in their structural features forming a very well defined cluster in the FWHM_{D1}/_Gvs- R_1 and FWHM_{D1}-vs- R_1 plots (Fig. 4.7 and 4.8). In this case the CM structural homogeneity can be more readily correlated to a common microbial molecular precursor.

Carbonaceous fluffy grains resemble clotted amorphous microbial remains observed in younger sediments (Fayers and Trewin, 2003; Trewin et al., 2003) and occur in association with mat-like laminae within the crinkly laminated chert. However, they are particularly abundant in the laminated black chert, where no evidence of mat-constructors has been observed. They are also possibly within the massive black chert, which is now disrupted by diffuse carbonaceous material, as suggested by the structural similarities between the grains and the cloudy material occurring in sample C9E (Tab. 4.4). Although there is a lack of evidence to provide better constrains on the origin of the carbonaceous grains, the occurrence of such clots within all the characterized facies and their clustering observed after Raman

investigation suggest that all the CM-rich grains may share a common origin, and that their precursor differ at least to a small extent, and it is wider than the molecular pool of the matlike structures.

4.2 Carbonaceous nanotexture of potential microbial mats

Simple and high-resolution (HR-) transmitted electron microscopy (TEM) allow in-situ high-resolution microscopy and microanalyses on the BARB3 CM, providing complementary results to the minero-petrography and Raman investigation. Particularly TEM is used to explore the CM features and distribution within the different microtextures at the nano-scale, while HR-TEM analyses allow the characterization of the CM nanotexture (or nanostructure) which is the mutual organization in space of the constitutive nanometric polyaromatic C-rich sheets forming the carbonaceous matter lattice. During HRTEM imaging, the profiles of individual polyaromatic planes are visualized as dark fringes and various parameters can be measured including their length, curvature, tortuosity and the inter-layer distance in the basic structural units (BSU) (Olcott Marshall et al., 2014; Apicella et al., 2015; Deldicque et al., 2016). As the carbonaceous nanotexture and lattice characteristics are dependent on the maturational process of the original carbonaceous precursor and its nature, HRTEM represent an important tool in ancient CM studies. A further advantage of CM high resolution studies is the possibility to discriminate minerals in the form of nanoparticles associated with the carbonaceous lattice, as the results could give insights concerning the original rock protholite and depositional conditions (Rasmussen et al., 2017) or into possible metabolic pathways exploited by microbial communities that are now represented in the form of carbonaceous remains (Westall et al., 2011). TEM and HRTEM analyses have been conducted on mat-like CM-rich laminae-sets from the crinkly laminated chert (sample F13B) and on the CM-rich network (sample C6D), found on top of the black granular chert, which has been interpreted as a possible microbial mat as supported by Raman analyses. Consequently, both potential microbial structures are explored here with the aim of investigating their nanotexture and to potentially discriminate minerals in the form of nanoparticles that could strengthen the microbial interpretation and suggest possible exploited metabolic pathways.

4.2.1 Carbonaceous lamina-sets vs carbonaceous networks

At TEM dark-field imaging FIB-lamellae from both microtextures (Fig. 4.9a and 4.10a) are characterized by the association between sparse CM nanometre-sized elongated clots (lower ass, dark grey) and quartz grains (higher mass, light grey) ranging in size from less than 1 μ m up to about 10 μ m wide. The CM appear interweaved between the chert crystals in a distribution which following the boundaries between the grains is consistent with the carbonaceous discontinuity already observed at the optical microscope scale (at 40X) and suggest that even for such well preserved microtextures a certain level of CM redistribution probably occurred. However both the network and lamina-sets-forming CM is characterized by a contact with the adjacent quartz grains which is non-linear but rather cuspate (Fig. 4.9b,c and 4.10b,c). At this contact the CM show patches of lighter grey due to the presence of low levels of silica or pervasive quartz nano-grains. Such non-linear partially silicified carbonaceous margins at the contact with the quartz crystals suggest that quartz nucleation started from the CM. This indicate that both the network and lamina-set where present prior to the silicification supporting their origin *in-situ* and thus their biogenicity rather than a remobilized CM trapping after chert crystallization (Brasier et al., 2002, 2005). On the other hand in the CM network nanotexture is possible to observe the presence of CM clots internal to the chert grains having a sub-spherical shape and characterized by regular margins at the contact with the surrounding quartz (Fig. 4.10a, Fig.4.11a,b). Such features suggest the presence of a CM remobilized phase which was trapped forming CM-rich inclusions during crystal growth after a silica-rich hydrothermal fluid (Wacey et al., 2012). This evidence is consistent with the interpretation of the stratiform botryoidal cavities as related to hydrothermal fluid circulation.

High resolution analyses have showed that both the investigated CM types have nanotextures that are largely homogeneous and consist mainly of turbostratic CM and isolated basic structural units (BSUs) a few nanometres long. In the BSU the aromatic layers interplanar distance of 3.6 Å correspond to a defective crystalline structure (Fig. 4.9d, Fig. 4.10d). In some cases in both the mat-like structures the fringes organized in 3.6 Å spaced stacks can reach about 20 nm in length. The nanotexture observed for both the carbonaceous mat-like structures is consistent with the structural organization of CM found at the end of the carbonization process as previously observed by Raman spectroscopic analyses (Delarue et al., 2016). TEM analyses have showed that the CM of the carbonaceous network is often associated with Fe, Cu, Ni-sulphides in the form of subhedral nanometre-sized crystal. The

significance of this occurrence require further investigation and the interpretation is still ongoing. Further HRTEM analyses on the microtextures defining the structural heterogeneity observed after Raman analyses are required.

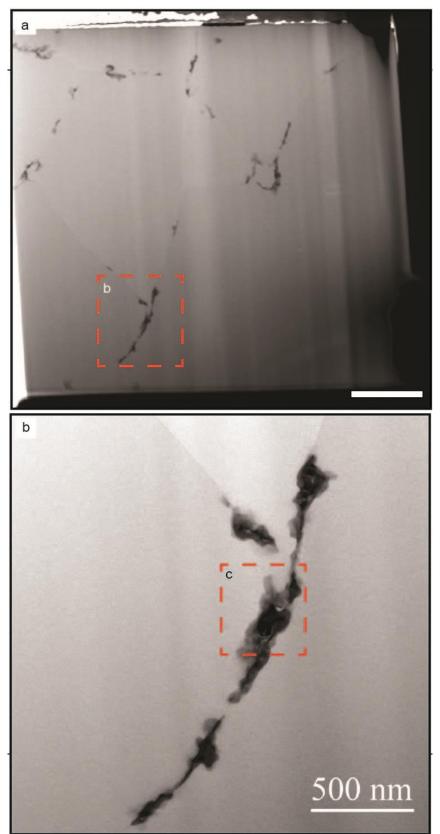


Figure 4.9a,b (continue) – CM forming the mat-like laminae occur in the form of nanometre-sized clots interleaved between chert crystals. a) CM from the lamina-sets occurring within the crinkly laminated chert sample F13. Scale bar: 2000 nm b) enlargement of the area in (a).

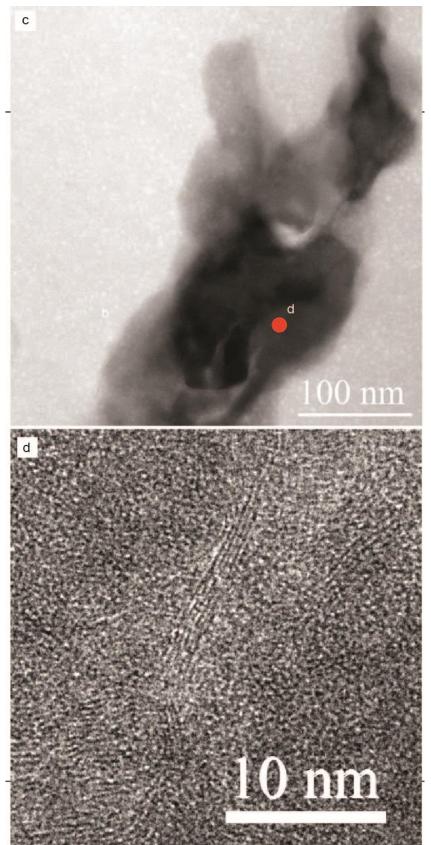


Figure 4.9c,d (continue) – c) The inset in (b) is enlarged. C) HRTEM image took on the red dot in (c).

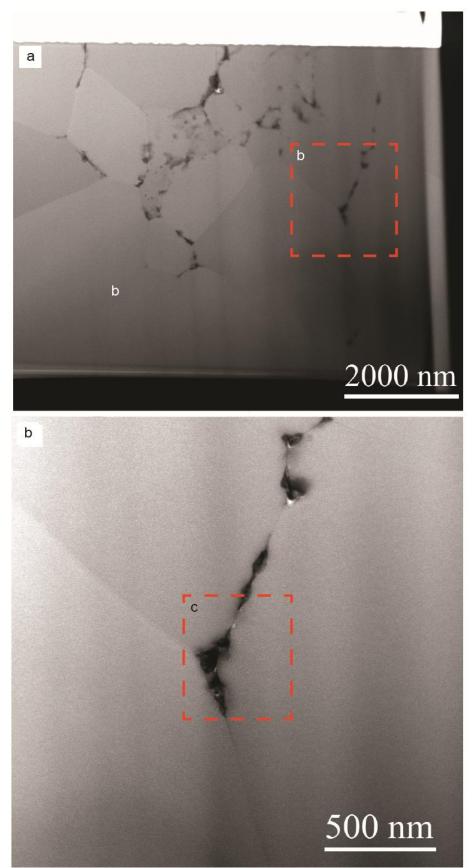


Figure 4.10a,b (continue) – CM forming the mat-like carbonaceous network occur in the form of nanometresized clots interleaved between chert crystals. a) CM from the lamina-sets occurring within the botryoidal quartz-filled vein at capping the granular carbonaceous chert of Sample C6D. b) enlargement of the area in (a).

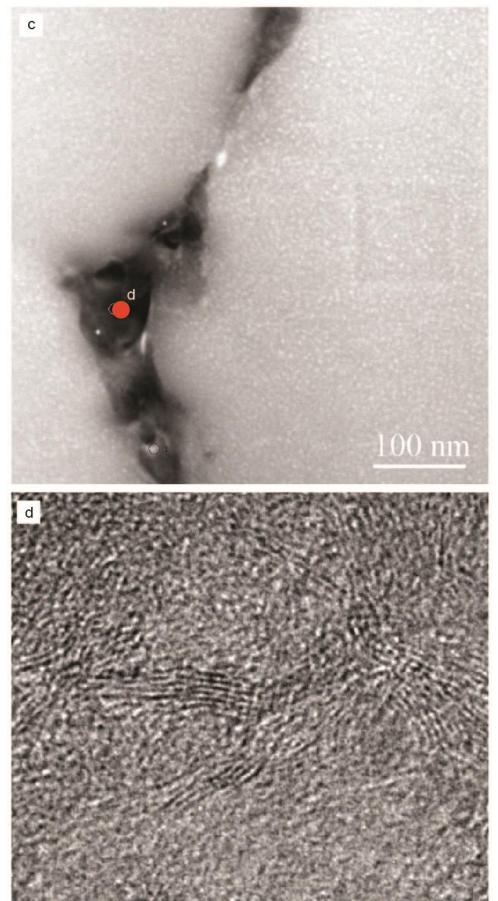


Figure 4.10c,d (continue) – c) The inset in (b) is enlarged. C) HRTEM image took on the red dot in (c).

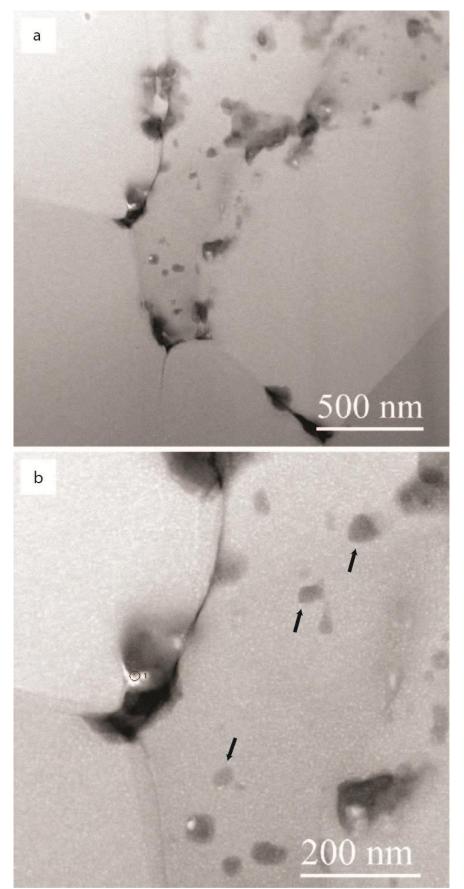


Figure 4.11 – a) In sample C6D ther than the CM associated to the network in the colloform-bending is possible to observe the presence of CM inclusion within the chert grains. b) The inclusions (black arrows) have a spheroidal shape characterized by regular margins at the contact with the surrounding quartz grain.

Chapter 5

Early microbial communities flourishing in a shallow-water hydrothermal field: a revisited Palaeoarchaean tale from the Buck Reef Chert

5.1 Discussion on the BAB3 core results

Understanding the significance of carbonaceous matter preserved in the ancient geological record represents a fundamental step to retrace the history of early microbial life on Earth. The task is challenging as ancient sedimentary deposits are scarce, often highly metamorphosed and formed under non-actualistic conditions, leading to problematic environmental reconstructions. Moreover widespread hydrothermalism on the Archaean Earth may affect our ability to discriminate biogenic CM. This is due to the potential input of abiotic carbon and the alteration of primary carbonaceous microtextures after chert crystallization out of the pervasive silica-rich fluids (Brasier et al., 2006, 2006; García-Ruiz et al., 2003; Wacey, 2009). Despite this, there are regions such as the 3.6 to 3.2 Ga years old Pilbara and Kaapvaal cratons, that offer well-preserved meta-sedimentary rocks where multiple reports of life, in the form of carbonaceous microbial remains have been documented (Altermann, 2001; Altermann and Kazmierczak, 2003; Schopf et al., 2007). It has also been shown how Palaeoarchaean CM may be better compared to the younger Precambrian biogenic carbonaceous record, rather than tested against an infinite set of null abiotic hypothesis (Walsh and Lowe, 1999; Tice and Lowe, 2006). Although, recognizing biotic CM in the fossil record is difficult, multiple lines of evidence indicate the existence of an early microbial biosphere from approximately 3.5 Ga years ago.

A classic location for studying ancient CM and the early evolution of microbial life is the 3.4 Ga old Buck Reef Chert of South Africa (Walsh, 1992; Walsh and Lowe, 1999; Tice and Lowe, 2006b). However, the environmental context in which the unit was deposited is still disputed (Hofmann, 2011). The observations resulting from this investigation on the BARB3 core and its carbonaceous content are herein discussed, including the palaeoenvironment of the Buck Reef Chert and its implications for the trophic identity of the BRC microbial communities. The outcome is a revisited picture from a corner of the early Earth.

5.1.1 Shallow-water diffuse hydrothermalism at the Buck Reef Chert

Previous outcrop investigations have discredited hydrothermalism at the BRC pointing at the absence of hot-springs or fluid conduits throughout the unit (Walsh and Lowe, 1999; Tice and Lowe 2006a,b). The BARB3 core however, provides this evidence in the form of stratiform botryoidal-quartz filled veins. Multiple observations support the origin of these structures as the result of sub-surface interactions between hydrothermal silica-rich fluids and a sediment column characterized by heterogeneous permeability. (I) Discrepancy in the timing of lithification of interbedded chert mesobands has been commonly observed in the BGB, whereas during early deposition white chert bands were already lithified occurring in alternation with carbonaceous-rich sediments that were not completely lithified (Lowe and Knauth, 1977; Lowe, 1999). In the BARB3 core, stratiform botryoidal veins developed as fractures within a crinkly laminated chert. This occurred immediately below a band of white chert with the two chert facies originally conformably superimposed (Fig. 3.16b). This is consistent with upwelling hydrothermal fluids, that get trapped by the non-permeable earlysilicified white chert bands, building overpressure, resulting in lateral veining through noncompletely lithified crinkly laminated layers. Analogous models have been already proposed for the generation of hydrothermal veining at the BGB (Paris et al., 1985; Hofmann and Bolhar, 2007; Hofmann and Harris, 2008). (II) The granular carbonaceous chert is a cavity filling facies found at the bottom of the stratiform veins. It is composed of CM-rich detritus mainly generated by the ripping-off, subsequent fluid-mediated transport and resedimentation of material previously deposited as a crinkly laminated layer. Nonhydrothermal models for the genesis of veins filled by granular carbonaceous material have been proposed. However, all models rely on the activity of currents that are responsible for the downward injection of detritus previously deposited at the sediment-water interface (Lowe, 1999; Tice and Lowe 2004, 2006). The BARB3 core bears no such evidence for current activity nor for granular carbonaceous layers that are formed directly at the sea-floor. The exclusive localization of granular-chert within stratiform veins is here regarded as proof of its genesis in the sub-surface due to lateral circulation of upwelling fluids within the sediment column. (III) The presence of botryoidal-quartz precipitate in the BARB3 core is the most definitive indicator for a hydrothermal nature of the circulating fluids. Colloformbanded quartz typically precipitates out of cooling-down colloidal silicothermal fluids in lowtemperature hydrothermal environments (Marinova et al., 2014; Prokofiev et al., 2017). In fact, the overall structure, texture and mineralogy of the BARB3 stratiform botryoidal veins are strikingly similar and find their best analogous to hydrothermal veins occurring in lowsulfidation epithermal systems (Marchev et al., 2004; Marinova et al., 2014; Papavassiliou et al., 2017) and sinters at subaerial and sublacustrine environments (Fournier et al., 1991; Guido and Campbell, 2012). Spheroidal CM inclusions within chert crystals at the colloformbending observed by TEM analyses (Fig. 4.10 and Fig. 4.11) and botryoidal carbonaceous rims around individual grains (Fig. 3.17c) in the granular chert indicate the trapping of a mobile CM-rich fluid phase by quartz precipitation and processes of spherulitic chert crystallization, both consistent with quartz precipitation out of a silica-rich hydrothermal gel (Brasier *et al.*, 2006; Wacey, 2009).

The presence of diffusively circulating silica-rich hydrothermal fluids in more permeable sediments is also supported by a combination of less explicit evidence; such as spherulitic precipitation around CM-siderite composite grains in fluid-intruded crinkly laminated chert (Fig. 3.8d,e), the presence in the same facies of fenestrae-like and lens-shaped cavities characterized by a colloform quartz precipitate and the role of such structures as internal silicification fronts in the ferruginous chert (Fig. 3.3a,b). More sporadic hydrothermal events of higher magnitude appear to be represented by the massive black chert mesobands. The mesobands are structureless and characterized by a greater abundance of pyrite, As,Ni,Co-sulphides and bituminous-interstitial CM. The massive black chert is better interpreted as a massive carbonaceous-rich hydrothermal vein mobilizing metals and viscous CM derived from the local thermal pyrolysis of carbonaceous debris recycled from the host rock (Buick, 1990; He et al., 2015; Suárez-Ruiz et al., 2016) or possibly from a different source of hydrothermal hydrocarbon input (Mazzini et al., 2004).

Multiple lines of evidence reveal that venting at the Buck Reef Chert is present, at least in the shallow-platformal lithofacies. The interaction between circulating fluids and noncompletely lithified sediments is also suggested by the presence of plastically deformed ripped-up mat-like laminae in the granular chert, indicating that hydrothermalism occurred early during the deposition of the unit. The absence of focused discharge zones, such as black smokers or massive sulphide deposits, is not a sufficient argument to exclude syn-depositional hydrothermalism at the BRC. The BARB3 core instead provides indications for a more diffuse hydrothermal discharge in a system characterized by low-temperature hydrothermal fluids pervading the unit veining and interfingering laterally within permeable layers. Similar features develop in low-sulfidation epithermal environments characterized by lowtemperature, low-pressure hydrothermal fluids migrating along the sediment bedding planes (Glasby et al., 2005). Diffuse hydrothermalism at the BRC shallow-platformal facies could have thus resulted from either a widespread heat flow that characterizes the hot hydrothermal Palaeoarchaean Earth (Hofmann 2011), or the unit being distally deposited from a focused discharge zone (Alt 1995; German and von Damm 2003). The observation in outcrop of an extensive CM-rich quartz dike (Fig. 3.19) cutting the Hooggenoeg Formation immediately below the BRC may advocate for the latter hypothesis representing a fluid conduit branching from a major distal discharge source.

The interpretation that several BARB3 sedimentary features are a result of syndepositional hydrothermalism, generates doubts concerning the BRC depositional palaeodepth reconstructions. The "shallow-platformal" facies, for which deposition was previously envisaged to be between 15 and 200 m (Tice and Lowe, 2004; 2006b), in the BARB3 core show no evidence of wave activity, nor of episodic storm events as both the granular chert and botryoidal cavities are better explained by hydrothermal fluid circulation. The restriction of mat-like laminations to this facies has been interpreted as a microbial community confined to the photic zone (Tice and Lowe 2004). Considering the absence of botryoidal stratiform veins, granular chert and black chert mesobands in the BIF section along the BARB3 core, it is here suggested that the differences between the shallow-platformal and deep-basinal lithofacies may instead reflect periods of quiescence in hydrothermalism rather than variation in the depositional depth or plausibly a combination of both. For instance, the subsidence of the volcanic platform may have increased pressure in the sedimentary column contrasting with the diffuse hydrothermal veining by low-temperature, low-pressure upwelling fluids in the "deep-basinal" facies. The most convincing evidence for shallowwater current activity at the BRC remains the observation of ripple-marks at the evaporitic facies (Lowe and Worrell, 1999; Tice and Lowe, 2004, 2006b). However, an unconformity has been reported between this basal section and the upper banded chert facies (Tice and Lowe, 2006b) preventing clear palaeodepth reconstructions.

In general the BARB3 facies has been deposited in a very low-energy environment. An extremely shallow depth, lower than previously reported, is suggested for the BRC shallow facies deposition. The porosity and band heterogeneity decreases upwards along the core and this advocates for an increasing depth in deposition for the BIF. Although this may additionally reflect a gradual closure in the venting system. Finally, any higher-energy current activity was confined to the evaporitic facies. The overall picture is consistent with a well-protected coastal-lagunal environment but either with a saline pond or lake.

5.1.2 Multiple carbonaceous generations

This study represent one of the few works which have found systematic variation in the structure of CM from Palaeoarchaean cherts constrained by field mapping and microfabric analysis. In particular it is showed how the BARB3 CM molecular structure varies depending on the analyzed facies and more specifically on the carbonaceous microtexture. Three major groups have been defined based on microtexture-related CM structural heterogeneity groups:

(I) microbial mat-like structures from the crinkly laminated chert and the granular carbonaceous chert (botryoidal vein); (II) CM-rich individual grains and (III) bitumeninterstitial dense CM. Such between-microtexture heterogeneity is indicative of multiple carbonaceous generations and suggests that divergence in the carbonaceous precursors and in the CM post-depositional histories are still preserved in the BRC and not completely masked by the metamorphic overprint.

A major structural divergence has been observed in the black massive chert CM assemblage characterized by a great abundance of bituminous-interstitial CM. A range of different explanations are consistent with such an observation. The massive black carbonaceous chert could have formed during hydrothermal events post-dating the BGB metamorphic peak reached at about 3.2 Ga years ago (Tice et al., 2004). In this way, the poorly ordered bituminous CM would be millions of years younger than the BRC deposits, and at the same time the co-occurring more mature cloudy CM could have been derived from the reworking of the ancient carbonaceous material originally deposited in the host-rock. However there are is no evidence for a younger hydrothermal event and the stratiform occurrence of the black massive chert, in the absence of clear hydraulic fracturing or hydrothermal breccia and dikes, fits better with an hydrothermally influenced deposit or an early carbonaceous stratiform hydrothermal veining through non-completely lithified rocks during the early stage of burial. At the same time the bitumen-like CM order doesn't differ much from that of the grains and the mat-like structures, fitting with the carbonization continuum of the Hooggenoeg and Kromberg formations (Fig. 4.8, Delarue et al., 2016), so causes other then the thermal imprint could be responsible for the structural heterogeneity.

It has been observed in younger organic rich sediments, that have gone through the oil window, that the thermal maturation of kerogen can result in the formation of a porous and cavity-filling aliphatic-rich asphaltite bitumen (Bernard et al., 2012). Similar occurrences have been reported from hydrothermally influenced deposits and methane seepage where organic debris can undergo thermal pyrolysis (Simoneit and Lonsdale, 1982; Savard et al., 1996; Kelly et al., 1995). The BARB3 bitumen-like CM, as indicated by the microtexture name, shows textural similarities to the interstitial bitumen that has been documented from coeval carbonaceous-rich and younger organic-rich deposits (Buick, 1990; He et al., 2015; Suárez-Ruiz et al., 2016). In fact, if such Palaeoarchaean bituminous CM originated from the concentration of aliphatic-rich carbonaceous molecules, then, at equal low P-T conditions, its thermal maturation would have proceeded much slower than other carbonaceous precursors that include more abundant aromatic compounds (Buseck and Huang, 1985; Jehlička et al.,

2003; Quirico et al., 2009; Marshall et al., 2010), as the aromatic C-rich compounds are more easily reorganized into polyaromatic graphite-like planes. It is well-known that the original CM composition affect its evolution within low-metamorphic sediments, with the most explicative case of a "precursor effect" represented by the so called non-graphitizing carbonaceous materials which even at extremely high temperature do not transform into graphite (Franklin, 1951). Thus the lower structural order of the BARB3 bituminous CM is consistent with a "precursor effect" whereas the original carbonaceous material was selectively enriched in aliphatic molecules. The interpretation of the massive black facies as a hydrothermal vein is consistent with bitumen formation and transportation as a viscous substance through veins or within adjacent deposits. This could explain the occurrence of such material in veinlets cross-cutting the other chert facies, or the localized evidence of bitumen-like spheres in the massive black chert and exceptionally, remobilized, in the crinkly laminated sample D1.

The structural homogeneity of CM in the carbonaceous networks and mat-like laminations could be correlated to a common microbial molecular precursor, , possibly Extracellular Polymeric Substances (EPS). These substances are the building blocks of the cohesive and plastic extracellular organic matrix used by microbes to secure themselves to the substrate and develop a complex colonial organization (Madigan et al., 1997). Such an interpretation is suitable for several reasons. First, all EPS are within the most resistant and most easily preserved microbial remains in ancient sedimentary deposits (Wacey, 2009; Kremer and Kaźmierczak, 2017). Including a limited amount of molecules when compared to the entire microbial molecular pool, it is reasonable to expect such an EPS precursor to result in a mature CM species characterized by a low standard deviation, or scattering, in their structural parameters. Last, the highest degree of carbonaceous structural order shown by the mat-like structures when compared to the other non-bituminous carbonaceous microtextures is consistent with the EPS being mostly composed by polysaccharides. Polysaccharides are characterized by the repeated hexagonal unit bearing 5 carbon atoms, and this could be potentially more prone to the carbonization/graphitization evolution than other molecular diverse biogenic products. Such a hypothesis is consistent with the use of natural polysaccharides as a suitable precursor to efficiently synthesise graphitic material (Chaldun et al., 2013; El Kadib, 2016) or in experiments where cellulose has been graphitized, yet still retains its original morphology (Kim et al., 2001).

5.1.3 Complex microbial communities at the BRC

During this investigation on the BARB3 drill core, no evidence for body microfossils was observed. Despite the exceptional state of preservation, the primary CM microtextures and the sedimentary microfabrics that are readily ascribable to microbial activity (the crinkly laminated chert) have not supplied any individual microfossils. This however, is not surprising but rather consistent with previous findings. Putative microfossils in the Palaeoarchaean are in fact extremely rare and their biogenicity is strongly debated (Schopf, 1993; Brasier *et al.*, 2005; Brasier *et al.*, 2006; Schopf *et al.*, 2007). Investigating the Barberton Greenstone Belt, Walsh and Lowe (1999) reported the presence of "possible fossils" in just 9 carbonaceous chert specimens out of more than 400 scrutinized samples. Tice and Lowe (2004, 2006) during their extensive work on the Buck Reef Chert CM provided only a single piece of morphological evidence that may be interpreted as possible filaments.

As documented here, not only does the diffuse CM, but also the primary carbonaceous structures, consist of an aggregation of individual sub-micron sized CM particles. This is confirmed by HRTEM analyses conducted on the carbonaceous mat-like laminae and network. Although such structures show morphological signatures supporting an originally cohesive precursor, at the nano-scale they lack carbonaceous continuity, consisting of nanometre-sized clots interweaved between chert crystals. Such observations are consistent with a certain degree of chert recrystallization (Knauth and Epstein, 1976; Knoll *et al.*, 1988) and with CM volume reduction during carbonization/graphitization, after the loss of the heteroatoms mass (Brooks and Taylor, 1965; Buseck and Huang, 1985). As both processes occur at low-metamorphic grade they are expected for such ancient meta-sedimentary deposits. Furthermore, chert spherulitic recrystallization, a process typical of Archaean hydrothermal cherts, is also capable of CM disaggregation (Brasier *et al.*, 2005; Brasier *et al.*, 2006). Evidence of spherulitic chert and botryoidal rims around grains within the BARB3 crinkly laminated and laminated black chert has been reported here.

If the carbonaceous mat-like structures, which are microtexturally and structurally consistent with a resistant EPS-rich precursor, have undergone disaggregation and CM displacement, then it is highly plausible that weak individual microfossils would now consist of sparse CM particles in the chert matrix. At the same time, CM redistribution at the cellscale, could have generated carbonaceous pseudo-fossils. Another potential explanation for the difficulty in the detection of individual microfossils concerns the possibility of nanobacteria communities (Southam and Donald, 1999; Walsh, 2004). Although this represents a fascinating avenue for future research it remains untested in the BRC.

Despite having not detected any individual microfossils, the BARB3 core represents a fantastic window to the Archaean world. In the facies corresponding to the so-called BRC shallow-platformal deposits (Tice and Lowe, 2006), there are several hundreds of meters of mat-like carbonaceous laminae that provides strong evidence for an original interaction between microbial communities and the surrounding environment. The crinkly laminated chert represents a bio-sedimentary microfabric and the thick lamina-sets developed periodically in response to cyclic environmental factors. Although carbonaceous mats from the BRC have been previously suggested to represent anoxygenic photosynthetic microbial communities living in a photic marine environment (Tice and Lowe, 2004, 2006), the planar stromatolite growth preserved in the crinkly laminated chert is consistent with a wide range of environmental settings, possibly supporting phototrophic and/or chemotrophic microbial communities (Mazzini et al., 2004; Hips and Haas, 2006; Mastrandrea et al., 2006; Gerdes, 2007; Noffke, 2009).

In the BARB3 core, carbonaceous networks about 100 µm thick gently coat the chert colloform precipitate, immediately overlying the granular carbonaceous chert facies. Such structures consist of a carbonaceous web that develops around fine quartz grains. These grains are well compacted and preferentially lay parallel to the bedding plane suggesting an original active trapping behaviour of the carbonaceous network (Eriksonn et al., 2007; Noffke, 2010). Similar cohesive carbonaceous networks have been previously reported from the BRC (Tice and Lowe, 2006) and have been regarded as the remains of microbial mats. The morphology and behaviour of the BARB3 carbonaceous networks are consistent with such a interpretation. This is further supported by Raman analyses, as the structural order of the networks overlap almost perfectly with that of carbonaceous mats preserved in the crinkly laminated chert. It is thus suggested that these structures may also derive from an EPS-rich precursor. However, while mat-like laminae preserved in the crinkly laminated chert probably represented epibenthic communities, the carbonaceous networks occur consistently within the botryoidal quartz-filled cavities, which are independent from the mechanism of formation and represent sub-surface environments.

The restriction of the carbonaceous network microtexture to the botryoidal veins suggests that a non-phototrophic microbial community adapted to sub-surface niches was present during the deposition of the BRC. This may discredit previous interpretations of the BRC mats, as exclusively photosynthetic (Tice and Lowe, 2004), an interpretation based

entirely on their confinement to a shallow photic zone (Tice and Lowe, 2006). Instead, independently to water depth, trophic sources other than solar light must have been present to sustain such cavity-colonizing microbial communities and may as well have supported sea-floor communities.

5.2 Synopsis

5.2.1 A revisited Palaeoarchaean tale from the Buck Reef Chert

The integration of observations obtained from a multiple analytical approach from the outcrop to the atomic scale provide a revisited picture for the Buck Reef Chert shallow facies and the hosted microbial communities. About 3.4 Ga years ago this corner of Earth was characterized by extremely calm shallow waters. Under the water column, soft-sediments were gently bubbling due to diffuse low-temperature, silica-rich hydrothermalism. Epibenthic mat-constructing communities flourished in such conditions resulting in the cyclic development of laterally extensive microbial carpets. Periods of intense microbial activity alternated to intervals of quick silicification at the sediment-water interface caused by silicarich hydrothermal fluids. The burial of early-lithified layers created non-permeable caps trapping the upwelling fluids and forcing them laterally through permeable organic-rich still soft sediments. The stratiform veining resulted in the remobilization of not yet lithified carbonaceous mats and microbial debris but represented as well the opportunity for a new ecological niche. Sub-surface chemotrophic dwelling microbial communities possibly colonized the stratiform veins resisting fluid circulation through a trapping-and-binding behaviour most commonly recognized in epibenthic communities. Eventually the veins sealed through precipitation of botryoidal silica out of the cooling silicothermal fluid.

Deeper in the sediment column higher temperature-pressure fluids resulted into the episodic opening of larger stratiform veins where insoluble CM was collected and recycled from the host-rocks. Here pyrolysis of microbial debris possibly occurred liberating an aliphatic rich viscous CM phase. Such CM was thus remobilized locally within sediments at the vein contact or distally through the conduits system up to the botryoidal stratiform veins. The viscous CM was eventually trapped by precipitating quartz or cooled down solidifying into asphaltite-like spheres and blobs.

5.2.2 Future perspectives

The original aim of this study was to: (I) recognize evidence of biological activity within the BARB3 core through the morpho-chemical characterization of potential microbial fossils; (II) investigate the provenance and relationships between CM in the different lithofacies to test theories for CM origin and evolution; (III) develop biosignatures, if any, and techniques for early life detection; (IV) contribute to the Paleoarchean environmental reconstruction. While points I, II and IV have been explicitly discussed in Chapter 3 and 4 to be further integrated in this section 5.1, point III has been so far only implicitly engaged. However it is clear from this investigation that, like for all the previous early Life studies, the search for a definitive biosignature ultimately rely on the integration of multiple analytical approaches from the outcrop to the atom scale.

Resulting in a revised picture of the Buck Reef Chert this research provide a starting point for future works finalized to better understand and constrain the structure of the hydrothermal system and its possible heat sources. The trophic identity and potential interaction between complex microbial communities should be also deeply investigated, especially focusing on the carbonaceous network biogenicity. A wise direction would be to extend the CM nanotexture characterization to all the microtextures that in this study showed a systematic structural variation and the integration of microtexture-based structural and textural results with in-situ C isotopic data. A confrontation of so-collected data with analogous information obtained from CM within the quartz-dike observed in outcrop and more generally from veins and deposits at the BRC basal-evaporitic facies and underlying horizons from the Hooggenoeg Formation would greatly improve our understanding of the C-cycle on the Palaeoarchaean Earth with major implication for the reconstruction of early Life evolution.

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Supplementary material

S1 – BARB3 samples

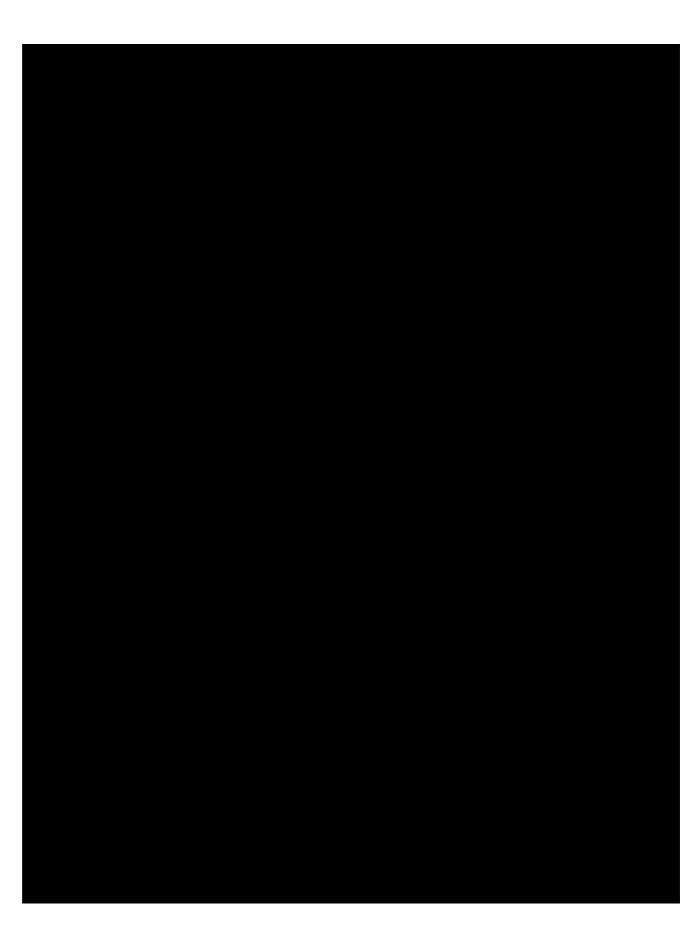
Crinkly laminated chert (clc), White chert (Wc), Stratiform botryoidal vein (Sbv), Granular carbonaceous chert (Gcc), Massive black chert (Mbc), Laminated black chert (Lbc), Siderite bands (Sb), Jasperlite bands (Jsp), Fractured chert (Fc).

	Core sample	De	pth	Box	Section	Facies	Core survey	Optical	IR		Raman	SEM	TEM
		From	То						in situ	bulk			
v	F 10	896.59	896.41	119	F13A	Clc	~	 ✓ 	-	-	~	~	-
	F13	896.59	896.41	119	F13B	Clc	~	 ✓ 	 ✓ 	-	~	~	~
	D1	896	895.9	119	D1	Clc	~	 ✓ 	~	-	~	>	-
	F12	895.9	895.67	119	F12	Clc -Wc-Sbv	~	 ✓ 	-	-	~	~	-
	F11	894.52	894.35	119	F11A	Clc	~	 ✓ 	-	-	~	-	-
	111	894.52	894.35	119	F11B	Clc	~	 ✓ 	-	-	V	~	-
		889.10	888.86	118	C9A	Gcc-Wc	~	 ✓ 	-	-	~	~	-
		889.10	888.86	118	C9B	Clc	~	~	-	-	~	-	-
	C9	889.10	888.86	118	C9C	Clc-Wc	~	~	-	-	~	~	-
		889.10	888.86	118	C9D	Clc-Mbc	~	~	-	~	~	~	-
		889.10	888.86	118	C9E	Mbc	~	 ✓ 	-	-	~	~	-
		887.54	887.30	118	F10A	Clc	~	~	-	-	~	-	-
	F10	887.54	887.30	118	F10B	Clc	~	 ✓ 	-	-	~	~	-
2		887.54	887.30	118	F10C	Clc	 ✓ 	 ✓ 	-	-	~	-	-
Shallow		869.8	869.67	116	D4A	Wc-Gcc	 ✓ 	~	-	-	~	-	-
Sha	D4	869.8	869.67	116	D4B	Clc	~	 ✓ 	-	-	V	~	-
		865.76	865.63	115	C8A	Mbc	~	 ✓ 	-	-	~	-	-
	C8	865.76	865.63	115	C8B	Mbc-Clc	~	 ✓ 	-	-	V	-	-
		865.76	865.63	115	C8C	Clc	 ✓ 	 ✓ 	-	-	~	-	-
	07	857.19	857.06	114	C7A	Wc-Clc-Gcc	~	 ✓ 	-	-	~	-	-
	C7	857.19	857.06	114	C7B	Gcc-Sbv-Wc	~	 ✓ 	v	-	~	-	-
	D5	845.06	844.91	113	D5	Clc	~	~	-	-	~	-	-
	D6	824.9	824.78	110	D6	Mbc-Clcc	~	 ✓ 	-	-	~	-	-
	D7	801.28	801.12	108	D7	Gcc	~	 ✓ 	-	-	-	-	-
		800	799.82	107	C6Z	Wc	~	 ✓ 	-	-	-	-	-
		800	799.82	107	C6A	Wc-Clc-Gcc-Sbv	V	 ✓ 	-	-	-	-	-
	C6	800	799.82	107	C6B	Gcc-Sbv-Wc-Clc	V	V	~	-	V	-	-
		799	799.81	106	C6C	Gcc-Sbv-Wc-Clc	V	V	~	-	V	-	-
^		800	799.82	107	C6D	Gcc-Sbv-Wc-Clc	~	~	-	-	~	~	~

	Core sample	De	pth	Box	Section	Facies	Core survey	Optical	I	R	Raman	SEM	TEM
v		794.39	794.12	107	C5A	Wc-Gcc	~	~	-	-	-	-	-
	C5	794.39	794.12	107	C5B	Wc-Gcc	~	~	-	-	-	-	-
	5	794.39	794.12	107	C5C	Wc-Mbc	~	~	-	-	-	-	-
		794.39	794.12	107	C5D	Wc-Mbc-Sbv	~	~	-	-	-	-	-
	D11	762.38	761.91	103	D11A	Clc	~	~	~	-	~	~	-
	DII	762.38	761.91	103	D11B	Clc	~	~	-	-	~	-	-
	F9	762.38	761.91	103	F9	Clc	~	~	~	-	~	-	-
		754.80	754.57	102	C4A	Wc-Clc-Gcc	~	~	-	-	~	-	-
	C4	754.80	754.57	102	C4B	Wc-Clc-Gcc	~	~	-	-	~	-	-
		754.80	754.57	102	C4C	Wc	~	~	-	-	~	-	-
Shallow	D12	712.06	711.85	96	D12	Wc-Clc	~	~	-	-	~	-	-
Shal		708.18	707.97	95	C3A	Clc-Wc-Gc	~	~	~	~	~	-	-
•7	C3	708.18	707.97	95	C3B	Clc-Wc-Gc-Sbv	~	~	~	-	~	-	-
		708.18	707.97	95	C3C	Clc-Wc-Gc-Sbv	~	~	~	-	~	-	-
	D13	699.28	699.1	93	D13	Wc-Lbc	~	~	-	-	-	-	-
	D15	664.04	663.79	88	D15A	Wc-Clc-Gcc	~	~	-	-	-	-	-
	015	664.04	663.79	88	D15B	Wc-Gcc	~	~	-	-	-	-	-
	F8	632.06	631.90	83	F8A	Wc-Clc	~	~	-	-	~	-	-
	ГО	632.06	631.90	83	F8B	Wc-Clc	~	~	-	-	~	-	-
		620.17	620.02	83	C2A	Gcc	~	~	-	-	~	-	-
	C2	620.17	620.02	83	C2B	Gcc-Sbv	~	~	~	-	~	-	-
^		620.17	620.02	83	C2C	Lbc	~	~	-	-	~	-	-
V	F7	583.03	582.79	79	F7	Sb-Wc	~	 ✓ 	-	-	-	-	-
	F6	554.54	554.42	74	F6	Sb-Wc	~	~	-	-	-	-	-
Deep	F5	538.30	538.08	72	F5	Sb-Wc-Jsp	~	~	-	-	~	~	-
De	F4	471.48	471.26	62	F4	Sb-Wc-Jsp	~	 ✓ 	-	-	~	~	-
	F3	419.13	418.88	55	F3A	Sb-Wc	~	~	-	-	-	-	-
^		419.13	418.88	55	F3B	Sb-Wc	~	 ✓ 	-	-	-	-	-

v		331.17	331.02	44	C1A	Fc	 ✓ 	~	-	-	~	-	-
≥	C1	331.17	331.02	44	C1B	Fc	~	~	>	-	~	-	-
allo		331.17	331.02	44	C1C	Fc	~	~	-	-	-	-	-
Sh	F2	256.29	256.10	33	F2	Wc-Clc	~	~	-	-	-	-	-
^	F1	250.77	250.61	32	F1	Wc-Clc	~	~	-	-	~	-	-

S1 – Raman dataset



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| | Facies | Sample | CM microtexture | N | А
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 |
| Crinkly | / laminated chert | D11A | Mat-like laminae | 1 | 54605.22
 | 1626.66

 | 1529.16
 | 23.35 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 2 | 54319.50
 | 1626.91

 | 1651.87
 | 21.45 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 3 | 43005.72
 | 1626.49

 | 1194.27
 | 23.55 |
 |
 | | | |
 |
| | laminated chert | D11A | Mat-like laminae | 4 | 62371.22
 | 1626.35

 | 1853.92
 | 21.96 |
 |
 | | | |
 |
| | / laminated chert | D11A
D11A | Mat-like laminae
Mat-like laminae | 5 | 86259.16
 | 1625.64

 | 2324.75
 | 24.28 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | D11A
D11A | Mat-like laminae
Mat-like laminae | 6
7 | 74042.11
62763.57
 | 1625.92
1626.25

 | 1715.04
1621.32
 | 28.39
25.37 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 8 | 65549.41
 | 1626.69

 | 1739.00
 | 24.68 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 9 | 49901.33
 | 1626.22

 | 1348.69
 | 24.21 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 10 | 96275.08
 | 1623.88

 | 2151.96
 | 29.45 |
 |
 | | | |
 |
| | / laminated chert | D11A | Mat-like laminae | 11 | 55243.41
 | 1625.56

 | 1473.34
 | 24.55 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | D11A
D11A | Mat-like laminae
Mat-like laminae | 12
13 | 63791.53
70868.64
 | 1626.03
1625.57

 | 1704.73
1745.03
 | 24.50
26.65 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 14 | 93992.49
 | 1623.32

 | 2056.13
 | 30.11 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 15 | 44088.16
 | 1626.22

 | 1193.18
 | 24.18 |
 |
 | | | |
 |
| Crinkly | / laminated chert | D11A | Grain | 16 | 64011.67
 | 1625.64

 | 1546.55
 | 27.18 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 17 | 24440.74
 | 1629.93

 | 910.69
 | 17.43 |
 |
 | | | |
 |
| | / laminated chert | D11A
D11A | Grain | 18 | 89771.40
63410.72
 | 1626.67

 | 2158.18
 | 27.32 26.64 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | D11A | Grain
Grain | 20 | 32007.95
 | 1626.93 1630.40

 | 1562.05
1221.95
 | 17.01 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 21 | 106658.46
 | 1624.92

 | 2370.26
 | 29.63 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 22 | 50728.55
 | 1627.32

 | 1348.28
 | 24.64 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 23 | 48970.21
 | 1627.67

 | 1393.83
 | 22.96 |
 |
 | | | |
 |
| | / laminated chert | D11A | Grain | 24 | 57047.59
 | 1626.50

 | 1556.80
 | 23.98 |
 |
 | | | |
 |
| Crinkly | / laminated chert | D11A | Grain | 25 | 61268.07
 | 1625.65

 | 1445.55
 | 27.85 |
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 |
| | Facilos | Comula | CM mierotouture | |
 | Lorentzian

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| 0 | Facies | Sample | CM microtexture | <u> </u> | A
 | ω

 | 2410 505
 | 20.724 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | C3A
C3A | Mat-like laminae
Mat-like laminae | 1 | 105509.358
68932.645
 | 1625.270
1626.285

 | 2416.567
1671.545
 | 28.724
27.082 |
 |
 | | | |
 |
| | / laminated chert | C3A
C3A | Mat-like laminae
Mat-like laminae | 2 | 68932.645
72479.840
 | 1626.285

 | 1671.545
 | 27.082 26.743 |
 |
 | | | |
 |
| | / laminated chert | C3A | Mat-like laminae | 4 | 105842.827
 | 1626.149

 | 2557.785
 | 27.178 |
 |
 | | | |
 |
| Crinkly | / laminated chert | C3A | Mat-like laminae | 5 | 51944.476
 | 1627.519

 | 1468.631
 | 23.125 |
 |
 | | | |
 |
| | laminated chert | C3A | Mat-like laminae | 6 | 67485.755
 | 1627.504

 | 1799.107
 | 24.566 |
 |
 | | | |
 |
| | / laminated chert | C3A
C3A | Mat-like laminae
Mat-like laminae | 7
8 | 73478.882
 | 1628.347

 | 2011.037
1424.184
 | 23.913
22.472 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | C3A | Mat-like laminae | 9 | 48978.810
97856.308
 | 1629.220
1627.371

 | 2264.211
 | 28.432 |
 |
 | | | |
 |
| | / laminated chert | C3A | Mat-like laminae | 10 | 58328.835
 | 1628.013

 | 1517.436
 | 25.194 |
 |
 | | | |
 |
| | / laminated chert | C3A | Mat-like laminae | 11 | 90381.601
 | 1627.215

 | 2176.892
 | 27.276 |
 |
 | | | |
 |
| | / laminated chert | C3A | Mat-like laminae | 12 | 79911.570
 | 1628.036

 | 2080.408
 | 25.176 |
 |
 | | | |
 |
| | laminated chert | C3A | Mat-like laminae | 13 | 51376.223
 | 1628.032

 | 1341.569
 | 25.097 |
 |
 | | | |
 |
| | / laminated chert
/ laminated chert | C3A
C3A | Mat-like laminae
Mat-like laminae | 14
15 | 35275.509
52271.979
 | 1628.722
1628.221

 | 1205.125
1685.250
 | 19.048
20.210 |
 |
 | | | |
 |
| | / laminated chert | C3A | Mat-like laminae | 16 | 46513.557
 | 1626.488

 | 1285.714
 | 23.662 |
 |
 | | | |
 |
| | / laminated chert | C3A | Grain | 17 | 52644.942
 | 1628.585

 | 1377.004
 | 25.053 |
 |
 | | | |
 |
| | / laminated chert | C3A | 0 | |
 |

 |
 | |
 |
 | | | |
 |
| | anninated chere | CSA | Grain | 18 | 53681.363
 | 1628.189

 | 1838.873
 | 18.995 |
 |
 | | | |
 |
| Crinkly | / laminated chert | C3A | Grain | 19 | 69455.472
 | 1627.241

 | 1721.879
 | 26.472 |
 |
 | | | |
 |
| Crinkly
Crinkly | / laminated chert
/ laminated chert | C3A
C3A | Grain
Grain | 19
20 | 69455.472
80631.474
 | 1627.241
1626.536

 | 1721.879
1828.041
 | 26.472
29.031 |
 |
 | | | |
 |
| Crinkly
Crinkly
Crinkly | / laminated chert
/ laminated chert
/ laminated chert | C3A
C3A
C3A | Grain
Grain
Grain | 19
20
21 | 69455.472
80631.474
63652.929
 | 1627.241
1626.536
1627.369

 | 1721.879
1828.041
1630.059
 | 26.472
29.031
25.149 |
 |
 | | | |
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| Crinkly
Crinkly
Crinkly
Crinkly | / laminated chert
/ laminated chert | C3A
C3A | Grain
Grain | 19
20 | 69455.472
80631.474
 | 1627.241
1626.536

 | 1721.879
1828.041
 | 26.472
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| Crinkly
Crinkly
Crinkly
Crinkly | / laminated chert
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/ laminated chert
/ laminated chert | C3A
C3A
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C3A | Grain
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Grain
Grain | 19
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80631.474
63652.929
64630.013
 | 1627.241
1626.536
1627.369
1627.132
1627.662

 | 1721.879
1828.041
1630.059
1662.396
 | 26.472
29.031
25.149
24.849 | R ₂ (1)
 | ΔT C° (2)
 | ΔT C° (3) | <mark>↓T C° (4</mark> | R _{D3} | R _{D4}
 |
| Crinkly
Crinkly
Crinkly
Crinkly
Crinkly
Crinkly | / laminated chert
/ laminated chert
/ laminated chert
/ laminated chert
/ laminated chert
Facies
/ laminated chert | C3A
C3A
C3A
C3A
C3A
Sample
C3A | Grain
Grain
Grain
Grain
Grain
CM microtexture
Mat-like laminae | 19
20
21
22
23
1 | 69455.472
80631.474
63652.929
64630.013
61628.289
R ₁
2.49
 | 1627.241
1626.536
1627.369
1627.132
1627.662
Г _{D1/G}
1.42

 | 1721.879
1828.041
1630.059
1662.396
1644.057
ID1/(ID1+IG
0.7132
 | 26.472
29.031
25.149
24.849
24.109
A _D /A _G
3.55 | 0.7157
 | 322.53
 | 350.66 | 340.25 | 0.0570 | 0.0533
 |
| Crinkly
Crinkly
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Crinkly
Crinkly
Crinkly | / laminated chert
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Facies
/ laminated chert
/ laminated chert | C3A
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CM microtexture
Mat-like laminae
Mat-like laminae | 19
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80631.474
63652.929
64630.013
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 | 1627.241
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1627.369
1627.132
1627.662
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 | 1721.879
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ID1/(ID1+IG
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A _D /A _G
3.55
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0.6979
 | 322.53
330.44
 | 350.66
358.31 | 340.25
351.38 | 0.0570
0.0439 | 0.0533
0.0499
 |
| Crinkly
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/ laminated chert
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CM microtexture
Mat-like laminae | 19
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80631.474
63652.929
64630.013
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R ₁
2.49
 | 1627.241
1626.536
1627.369
1627.132
1627.662
Г _{D1/G}
1.42

 | 1721.879
1828.041
1630.059
1662.396
1644.057
ID1/(ID1+IG
0.7132
 | 26.472
29.031
25.149
24.849
24.109
A _D /A _G
3.55 | 0.7157
 | 322.53
 | 350.66
358.31
355.62 | 340.25 | 0.0570 | 0.0533
 |
| Crinkly
Crinkly
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Facies
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C3A | Grain
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Grain
CM microtexture
Mat-like laminae
Mat-like laminae
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Mat-like laminae
Mat-like laminae | 19
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4
5 | 69455.472
80631.474
63652.929
64630.013
61628.289
R ₁
2.49
2.49
2.40
2.51
2.62
2.30
 | 1627.241
1626.536
1627.369
1627.132
1627.662
F _{D1/G}
1.42
1.24
1.38
1.31
1.26

 | 1721.879
1828.041
1630.059
1662.396
1644.057
ID1/(ID1+IG
0.7132
0.7056
0.7150
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					Lorentzian	(D4)			Lorentzian	(D1)	
Facies	Sample	CM microtexture		A	ω	1	Г	A	ω	1	Г
Crinkly laminated chert	D1	Bitumen-like	1	144127.42	1201.35	504.45	218.50	781040.688	1354.020	6509.423	81.001
Crinkly laminated chert Crinkly laminated chert	D1 D1	Bitumen-like Bitumen-like	2	135532.14 249840.79	1200.06	496.60 680.20	206.66 300.91	783847.183 1022100.000	1353.994 1354.021	6514.104 8412.418	81.248
Crinkly laminated chert	D1	Bitumen-like	4	129534.26	1196.40	512.21	188.72	828064.969	1354.006	6925.444	80.701
Crinkly laminated chert	D1	Bitumen-like	5	148087.60	1195.61	651.36	166.44	1075840.000	1353.437	8830.643	82.327
Crinkly laminated chert Crinkly laminated chert	D1 D1	Bitumen-like Bitumen-like	6	145429.08 130413.23	1197.32	560.51 575.02	194.56 166.23	931972.906 906514.984	1354.062 1353.756	7757.765 7433.069	81.107 82.418
Crinkly laminated chert	D1	Bitumen-like	8	170685.50	1196.71	588.87	222.80	925209.721	1353.831	7624.203	81.982
Crinkly laminated chert	D1	Bitumen-like	9	148047.62	1196.20	588.57	187.53	948567.987	1353.906	7881.077	81.269
Crinkly laminated chert	D1 D1	Bitumen-like	10	134972.35	1196.66	556.95	179.37	910638.057	1354.299	7595.130	80.937
Crinkly laminated chert Crinkly laminated chert	DI	Bitumen-like Bitumen-like	12	124668.24 148578.74	1197.66 1196.78	489.18 615.18	190.39 178.64	800295.734 976519.402	1353.714 1353.421	6645.324 7951.105	81.319 83.036
Crinkly laminated chert	D1	Bitumen-like	13	117596.22	1195.22	520.40	165.28	855719.664	1353.437	6990.227	82.749
Crinkly laminated chert	D1	Bitumen-like	14	166188.69	1193.42	676.44	182.49	1182080.000	1353.149	9666.371	82.656
Crinkly laminated chert Crinkly laminated chert	D1 D1	Bitumen-like Bitumen-like	15	168415.93 89120.89	1197.26 1197.24	620.24 392.04	205.58	999239.470 726273.359	1354.019 1354.404	8257.722 6271.580	81.734 78.004
Crinkly laminated chert	D1	Bitumen-like	17	293098.22	1202.40	1043.79	213.81	1683330.000	1355.560	17523.545	64.042
Crinkly laminated chert	D1	Bitumen-like	18	139182.01	1194.33	696.17	143.53	1023930.000	1353.782	8424.063	82.123
Crinkly laminated chert Crinkly laminated chert	D1 D1	Bitumen-like Bitumen-like	19	170446.93 174423.91	1196.44 1202.62	676.18 670.55	187.99 194.82	1086200.000 1042770.000	1353.999 1355.007	8989.516 9495.793	81.607
Crinkly laminated chert	D1	Bitumen-like	21	236358.77	1206.49	853.09	210.04	1268900.000	1355.023	10260.269	83.653
Crinkly laminated chert	D1	Bitumen-like	22	137903.78	1194.25	544.47	189.20	880652.234	1354.329	7258.862	81.960
Crinkly laminated chert	D1	Bitumen-like	23	156634.98	1197.71	623.21	186.24	1010969.79	1353.94	8320.53	81.93
					Lorentzian	(D4)			Lorentzian	· · ·	
Facies	Sample	CM microtexture		A	ω	1	Г	A	ω	1	Г
Massive black chert	C9E C9E	Bitumen-like Bitumen like	1	148802.95	1211.33	451.45	260.26	643787.16	1355.13	5929.04	72.84
Massive black chert Massive black chert	C9E	Bitumen-like Bitumen-like	2 3	26147.32 30824.76	1199.49 1202.91	133.58 139.86	139.85 160.09	239131.16 270621.17	1351.19 1353.29	1793.80 2488.38	90.62 72.97
Massive black chert	C9E	Bitumen-like	4	25587.66	1203.63	139.96	129.37	233500.62	1350.50	1697.23	93.73
Massive black chert	C9E	Bitumen-like	5	34238.01	1206.04	134.25	190.03	216234.26	1355.31	1873.77	77.72
Massive black chert Massive black chert	C9E C9E	Bitumen-like Bitumen-like	6 7	48892.59 190025.45	1206.08 1204.29	227.92 710.39	155.15 201.36	401032.89 1186100.000	1353.62 1352.447	3290.89 10080.343	82.35 79.337
Massive black chert	C9E	Bitumen-like	8	11288.33	1195.22	63.13	126.46	126974.178	1356.144	1137.789	75.005
Massive black chert	C9E	Bitumen-like	9	59184.69	1202.57	238.38	184.11	368973.616	1352.815	2948.212	84.698
Massive black chert Massive black chert	C9E C9E	Bitumen-like Bitumen-like	10 11	82638.26 58555.68	1207.88 1202.00	268.18 274.95	239.22 154.01	396141.581 457474.324	1352.007 1355.379	3153.828 4168.249	85.027 73.694
Massive black chert	C9E	Bitumen-like	12	91470.80	1219.16	355.18	191.58	545579.329	1354.114	4946.864	74.074
Massive black chert	C9E	Bitumen-like	13	72495.17	1206.37	261.21	194.33	410118.80	1352.96	3460.46	82.37
Massive black chert Massive black chert	C9E C9E	Bitumen-like Interstitial	14	225586.28 97069.56	1227.58	702.71 345.46	250.47 212.51	989872.803 562909.810	1353.750 1353.193	9219.415 5047.286	72.003
Massive black chert	C9E	Interstitial	16	39548.89	1207.96	151.47	195.36	233631.197	1354.738	2177.860	71.937
Massive black chert	C9E	Interstitial	17	134780.24	1223.47	319.66	361.83	504482.497	1355.511	4872.111	69.301
Massive black chert Massive black chert	C9E C9E	Cloudy Cloudy	18 19	39966.01 237929.62	1209.52 1245.36	166.97 617.16	176.11 316.00	266380.603 742911.451	1356.107 1355.227	2703.049 7988.333	65.786 61.892
Massive black chert	C9E	Cloudy	20	293098.22	1202.40	1043.79	213.81	1683330.000	1355.560	17523.545	64.042
Massive black chert	C9E	Cloudy	21	239808.65	1246.68	626.10	313.09	739770.221	1355.229	7988.321	61.618
Massive black chert	C9E	Cloudy					216.17				
Massive black chert	COE		22	52140.81	1237.04	182.36		226854.927	1353.988	2355.363	64.206
Massive black chert	C9E	Cloudy	22	50733.42	1235.26	181.68	210.14	227898.705	1353.981	2358.814	64.417
		Cloudy		50733.42	1235.26 Gaussian	181.68 (D3)	210.14	227898.705	1353.981 Lorentziar	2358.814 1 (G)	64.417
Facies	C9E Sample D1	Cloudy CM microtexture		50733.42 A	1235.26 Gaussian ω	181.68 (D3) /	210.14 <i>Г</i>	227898.705 A	1353.981 Lorentziar ω	2358.814 n (G) /	64.417 Г
	Sample	Cloudy	23 1 2	50733.42 A 81139.014 84247.965	1235.26 Gaussian 0 1551.531 1553.306	181.68 (D3)	210.14	227898.705	1353.981 Lorentziar <u> </u> 1606.072 1605.348	2358.814 1 (G)	64.417
Facies Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert	D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like	23 1 2 3	50733.42 A 81139.014 84247.965 110234.967	1235.26 Gaussian 0 1551.531 1553.306 1551.837	181.68 (D3) / 616.518 649.703 832.472	210.14 123.638 121.818 124.399	227898.705 A 249454.102 231471.362 309154.216	1353.981 Lorentziar <u>w</u> 1606.072 1605.348 1604.520	2358.814 (G) 3876.344 3733.886 4808.418	64.417 42.875 41.224 42.822
Facies Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4	50733.42 A 81139.014 84247.965 110234.967 81274.197	1235.26 Gaussian 0 1551.531 1553.306 1551.837 1551.485	181.68 (D3) / 616.518 649.703 832.472 661.178	210.14 123.638 121.818 124.399 115.479	227898.705 A 249454.102 231471.362 309154.216 214316.034	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485	2358.814 1 (G) 3876.344 3733.886 4808.418 3496.225	64.417 42.875 41.224 42.822 40.729
Facies Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like	23 1 2 3	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040	1235.26 Gaussian 0 1551.531 1553.306 1551.837	181.68 (D3) / 616.518 649.703 832.472	210.14 123.638 121.818 124.399 115.479 126.505 114.495	227898.705 A 249454.102 231471.362 309154.216	1353.981 Lorentziar <u>w</u> 1606.072 1605.348 1604.520	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699	64.417 42.875 41.224 42.822
Facies Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7	50733.42 A 81139.014 84247.965 110233.4967 81274.197 117812.291 96482.040 99740.363	1235.26 Gaussian <u>w</u> 1551.531 1553.306 1551.837 1551.485 1554.320 1554.486 1554.801	181.68 (D3) 616.518 649.703 832.472 661.178 874.884 791.638 797.880	210.14 123.638 121.818 124.399 115.479 126.505 114.495 117.436	227898.705 A 249454.102 231471.362 309154.216 214316.034 233513.843 237663.586 221909.302	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.635 1603.396 1602.708	2358.814 (G) / 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231	64.417 42.875 41.224 42.822 40.729 42.695 39.581 39.337
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7 8	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049	1235.26 Gaussian 551.531 1551.531 1551.485 1551.485 1554.486 1554.486 1554.801 1558.045	181.68 (D3) 616.518 649.703 832.472 661.178 874.884 791.638 797.880 799.461	210.14 123.638 121.818 124.399 115.479 126.505 115.479 126.505 114.495 117.436 123.058	227898.705 A 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988	1353.981 Lorentziar ω 1606.072 1603.348 1604.520 1603.485 1603.635 1603.396 1602.708 1602.708	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609	64.417 42.875 41.224 42.822 40.729 42.695 39.581 39.337 40.723
Facies Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7	50733.42 A 81139.014 84247.965 110233.4967 81274.197 117812.291 96482.040 99740.363	1235.26 Gaussian <u>w</u> 1551.531 1553.306 1551.837 1551.485 1554.320 1554.486 1554.801	181.68 (D3) 616.518 649.703 832.472 661.178 874.884 791.638 797.880	210.14 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060	227898.705 A 249454.102 231471.362 309154.216 214316.034 233513.843 237663.586 221909.302	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.635 1603.396 1602.708	2358.814 (G) / 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231	64.417 42.875 41.224 42.822 40.729 42.695 39.581 39.337 40.723 39.873 39.873 43.020
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 6 7 7 8 9 10 11	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 90889.988	1235.26 Gaussian 0 1551.531 1553.306 1551.487 1554.486 1554.486 1554.486 1554.486 1558.045 1558.045 1550.700 1544.128 1558.370	181.68 (D3) / 616.518 832.472 661.178 874.884 791.638 797.880 799.461 766.662 634.839 700.319	210.14 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060 121.924	227898.705 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.045 193056.281	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.345 1603.365 1603.396 1602.708 1604.009 1602.560 1603.536 1603.173	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3944.699 3742.231 4005.609 3836.014 3915.664 3285.541	64.417 42.875 41.224 42.822 40.729 42.695 39.387 40.723 39.873 43.020 38.967
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 10 11 11	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 997421.424 76401.849 90889.988 113871.145	1235.26 Gaussian 555.331 1551.337 1551.485 1554.807 1554.801 1558.045 1558.045 1558.0700 1544.128 1558.370	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 797.880 797.880 799.461 796.662 634.839 700.319 820.680	210.14 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060 121.924 130.350	227898.705 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.495 1603.635 1603.396 1602.708 1604.009 1602.560 1603.536 1603.537 1603.482	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431	64.417 42.875 41.224 42.822 40.729 42.695 39.581 39.337 40.723 39.873 40.723 39.873 40.723 39.873 40.203 40.850
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 6 7 7 8 9 10 11	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 90889.988	1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.837 1554.320 1554.320 1554.4861 1554.320 1554.4861 1558.045 1558.0700 154.128 1558.370 154.376 154.376 1556.947 1547.316	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 791.638 797.880 799.461 799.461 766.662 634.839 700.319 820.680 624.013	210.14 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060 121.924 130.350 115.190	227898.705 249454.102 231471.362 309154.216 214316.034 23363.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786	1353.981 Lorentziar ω 1606.072 1605.348 1603.485 1603.485 1603.363 1602.560 1602.560 1603.373 1603.362	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230	64.417 42.875 41.224 42.822 40.729 42.695 39.387 40.723 39.873 43.020 38.967
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 104722.049 94621.424 104722.049 94621.424 13871.145 76513.960 132448.332 110470.471	1235.26 Gaussian 0 1551.531 1553.306 1551.837 1551.485 1554.320 1554.486 1554.4861 1558.045 1550.700 1544.128 1558.370 1547.316 1554.747 1555.271	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 797.880 799.461 766.662 634.839 700.319 820.680 624.013 975.609 866.164	210.14	227898.705 A 249454.102 231471.362 214316.034 235513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198	1353.981 Lorentzian 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.336 1602.708 1602.560 1602.560 1603.472 1603.482 1603.482 1603.608 1603.482 1603.608 1603.482 1603.608 1604.486	2358.814 (G) 1 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064	64.417 42.875 41.224 42.8275 41.224 42.822 40.729 42.695 39.337 40.723 39.873 43.020 43.020 43.551 41.598 40.789
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 9 10 11 11 12 13 14 14 15 16	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 994621.424 76401.849 90889.988 113871.145 76513.960 132448.332 110470.471 72087.414	1235.26 Gaussian	181.68 (D3) / 649.703 832.472 661.178 874.884 791.638 797.880 797.880 797.880 700.319 820.680 624.013 975.609 866.164 548.111	210.14 1 23.638 121.818 124.399 115.479 112.495 117.436 117.436 113.060 121.924 130.350 121.924 130.350 121.924 130.350 121.5190 127.538 119.816 123.555	227898.705 249454.102 231471.362 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.044 193056.281 251880.273 24506.786 326564.198 277536.267	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.635 1603.635 1603.635 1603.635 1603.635 1603.396 1602.708 1603.536 1603.462 1603.463 1603.463 1603.463 1603.465 1603.165 1602.229	2358.814 1 (G) 1 (3876.344 3733.886 4808.418 3496.225 4421.517 988.609 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230.696 4521.064 4521.064 4518.621	64.417 42.875 41.224 42.822 40.723 39.337 40.723 39.337 40.723 39.387 40.723 39.387 40.723 40.723 40.723 40.725 40.797 40.596 40.797 47.797
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1 D1	Cloudy CM microtexture Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15	50733.42 A 81139.014 84247.965 110234.967 117812.291 96482.040 99740.363 104722.049 994621.424 76401.849 9088.988 113871.145 76513.960 132448.332 110470.4711 72087.414 110888.820	1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.485 1554.320 1554.320 1554.4861 1558.045 1554.747 1556.947 1556.271 1538.250 1541.386	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 797.880 799.461 766.662 634.839 700.319 820.680 624.013 975.609 866.164	210.14	227898.705 A 249454.102 231471.362 214316.034 235513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198	1353.981 Lorentzian 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.336 1602.708 1602.560 1602.560 1603.472 1603.482 1603.482 1603.608 1603.482 1603.608 1603.482 1603.608 1604.486	2358.814 (G) 1 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064	64.417 42.875 41.224 42.8275 41.224 42.822 40.729 42.695 39.337 40.723 39.873 43.020 43.020 43.551 41.598 40.789
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like	23 1 2 3 4 5 6 7 8 9 10 111 12 13 14 15 16 17 17 18 19	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 90889.988 113871.145 76513.960 132448.332 110470.471 132448.332 110470.471 110889.820 114886.137 100901.822	1235.26 Gaussian υ 1551.531 1553.306 1551.837 1551.485 1554.320 1554.320 1554.320 1554.320 1554.320 1558.045 1558.045 1558.045 1558.047 1556.947 1555.2711 1538.250 1541.386 1558.910 1551.396	181.68 (D3) / / 616.518 649.703 832.472 661.178 874.884 799.880 799.461 766.662 634.839 790.840 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029	210.14 Г 123.638 121.818 124.399 115.479 126.505 117.436 123.058 113.060 121.924 130.350 115.190 127.538 119.816 123.555 115.603 119.279 125.215	227898.705 249454.102 231471.362 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 3265564.198 277536.267 272692.790 599404.068 273586.080 340452.029	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.635 1603.635 1603.635 1603.635 1603.635 1603.635 1603.636 1603.536 1603.638 1603.648 1603.608 1603.608 1603.628 1603.628 1603.628 1603.638 1604.486 1602.229 1603.953 1604.877 1605.336	2358.814 1 (G) 1 (G)	64.417
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 9088.988 113871.145 76513.968 1132448.332 110470.471 72087.414 110889.820 114886.137 100901.822 96074.261	1235.26 Gaussian 551.531 1553.306 1551.837 1551.485 1554.320 1554.320 1554.320 1554.320 1554.320 1558.370 1558.370 1558.370 1558.370 1554.747 1555.271 1538.250 1541.386 1558.310	181.68 (D3) / 616.518 649.703 832.472 832.472 791.638 799.461 799.461 799.461 799.461 799.461 799.461 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465	210.14 F 123.638 121.818 124.399 115.479 112.436 113.660 123.058 115.945 113.060 121.924 130.350 121.924 130.350 127.538 119.816 123.555 119.8216 123.555 119.279 125.215 121.2236	227898.705 249454.102 231471.362 309154.216 214316.034 233615.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 326564.198 326564.198 326564.198 3277535.267 2772692.790 599404.068 327356.080 340452.029 327065.491	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.396 1602.708 1602.708 1603.473 1603.482 1603.608 1603.608 1602.229 1603.953 1604.877 1605.336 1604.373	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8988.087 4571.685 5174.524 5174.524	64.417 42.875 41.224 42.825 42.825 42.822 42.695 39.581 40.723 39.581 40.723 39.587 40.723 39.9873 40.723 38.967 40.850 43.526 41.598 40.797 47.977 44.965 39.728 39.728 39.728 39.728 43.9877 44.9877 43.98777 43.98777 43.987777 43.98777777777777777777777777777777777777
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 7 8 9 9 10 111 123 14 15 16 16 16 17 18 19 20 21	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 994621.424 76401.849 9088.988 113871.145 102448.332 110470.471 12248.332 110470.471 11486.137 100901.822 96074.261 163183.065	1235.26 Gaussian υ 1551.531 1553.306 1551.837 1551.485 1554.320 1554.320 1554.320 1554.320 1556.947 1556.947 1555.271 1558.273 1555.271 1538.250 1551.386 1558.290 1551.386 1558.910 1551.196 1538.629	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 799.461 799.461 799.461 799.461 799.461 799.461 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465	210.14 7 123.638 121.818 124.399 115.479 115.479 115.479 115.479 115.495 117.436 123.058 115.945 115.945 115.945 115.945 115.060 115.190 127.538 119.279 125.215 119.279 125.215 121.236 140.021	227898.705 249454.102 231471.362 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.0445.622 252903.0445.622 252903.046.786 326564.198 277536.267 24506.786 326564.198 277536.267 2725692.790 599404.068 273586.080 340452.029 327065.491 327265.491	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.635 1602.708 1602.708 1602.708 1603.536 1603.482 1603.65 1603.482 1603.65 1604.486 1602.229 1603.853 1604.353 1604.534	2358.814 1 (G) 1 (G)	64.417
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like	23 1 2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18 19 20	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 104722.049 94621.424 76401.849 9088.988 113871.145 76513.968 112448.332 110470.471 72087.414 110889.820 114886.137 100901.822 96074.261	1235.26 Gaussian 551.531 1553.306 1551.837 1551.485 1554.320 1554.320 1554.320 1554.320 1554.320 1558.370 1558.370 1558.370 1558.370 1554.747 1555.271 1538.250 1541.386 1558.310	181.68 (D3) / 616.518 649.703 832.472 832.472 791.638 799.461 799.461 799.461 799.461 799.461 799.461 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465	210.14 F 123.638 121.818 124.399 115.479 112.436 113.660 123.058 115.945 113.060 121.924 130.350 121.924 130.350 127.538 119.816 123.555 119.8216 123.555 119.279 125.215 121.2236	227898.705 249454.102 231471.362 309154.216 214316.034 233615.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 326564.198 326564.198 326564.198 3277535.267 2772692.790 599404.068 327356.080 340452.029 327065.491	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.396 1602.708 1602.708 1603.473 1603.482 1603.608 1603.608 1602.229 1603.953 1604.877 1605.336 1604.373	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8988.087 4571.685 5174.524 5174.524	64.417 42.875 41.224 42.825 42.825 42.822 42.695 39.581 40.723 39.581 40.723 39.587 40.723 39.9873 40.723 38.967 40.850 43.526 41.598 40.797 47.977 44.965 39.728 39.728 39.728 39.728 43.9877 44.9877 43.98777 43.98777 43.987777 43.98777777777777777777777777777777777777
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like	23 1 2 3 4 5 6 6 7 7 8 9 100 111 122 133 14 15 16 16 17 17 18 19 200 21 22	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 104722.049 94621.424 104722.049 94689.988 113871.145 76513.960 132448.332 110470.471 72087.414 110889.820 114866.137 100901.822 96074.261 163183.065 89369.269	1235.26 Gaussian 551.531 1553.306 1551.487 1551.487 1554.320 1554.486 1554.801 1558.045 1554.801 1558.045 1554.747 1558.370 1547.316 1554.747 1555.271 1538.250 1541.386 1558.910 1541.486 1558.910 1544.465 1544.465 1544.465 1534.629 1554.932	181.68 (D3) / 616.518 649.703 832.472 791.638 797.880 799.461 799.461 766.662 634.839 7700.319 820.680 624.013 975.609 866.164 904.841 757.029 744.465 1094.847 701.100 823.61	210.14 7 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060 121.924 130.350 115.190 115.190 115.190 115.190 115.2355 115.603 119.279 125.215 121.236 140.021 119.750	227898.705 A 249454.102 231471.362 214316.034 23513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 277535.267 272592.790 599404.068 2775358.080 340452.029 3	1353.981 Lorentzian 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.635 1603.635 1602.708 1602.500 1602.500 1603.173 1603.482 1603.608 1603.608 1604.877 1605.336 1604.877 1605.336 1604.873 1604.874 1605.488	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.633 3285.541 4097.431 3750.230 5220.696 4521.064 4521.064 4521.064 5174.524 4958.295 7257.978 4171.490	64.417 42.875 41.224 42.825 42.825 42.822 42.695 39.581 39.581 39.581 39.581 39.581 40.723 39.67 40.723 39.67 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.787 40.725 39.787 40.725 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.7797 40.787 40.787 40.787 40.787 40.723 40.725 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like	23 1 2 3 4 5 6 6 7 7 8 9 100 111 122 133 14 15 16 16 17 17 18 19 200 21 22	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 104722.049 94621.424 104722.049 94689.988 113871.145 76513.960 132448.332 110470.471 72087.414 110889.820 114866.137 100901.822 96074.261 163183.065 89369.269	1235.26 Gaussian 551.531 1553.306 1551.485 1551.485 1554.320 1554.486 1554.486 1558.045 1558.045 1558.045 1558.045 1558.045 1558.045 1558.370 1547.47 1555.271 1538.250 1541.386 1538.426 1558.910 1551.196 1544.485 1538.629 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1550.28	181.68 (D3) / 616.518 649.703 832.472 791.638 797.880 799.461 799.461 766.662 634.839 7700.319 820.680 624.013 975.609 866.164 904.841 757.029 744.465 1094.847 701.100 823.61	210.14 7 123.638 121.818 124.399 115.479 126.505 114.495 117.436 123.058 115.945 113.060 121.924 130.350 115.190 115.190 115.190 115.190 115.2355 115.603 119.279 125.215 121.236 140.021 119.750	227898.705 A 249454.102 231471.362 214316.034 23513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 277535.267 272592.790 599404.068 2775358.080 340452.029 3	1353.981 Lorentziar 0 1606.072 1605.348 1603.635 1603.635 1603.635 1603.635 1602.708 1602.708 1603.452 1603.356 1603.173 1603.452 1603.608 1603.163 1603.259 1604.534 1605.348 1605.348 1605.348 1605.348 1605.348 1605.359	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.633 3285.541 4097.431 3750.230 5220.696 4521.064 4521.064 4521.064 5174.524 4958.295 7257.978 4171.490	64.417 42.875 41.224 42.825 42.825 42.822 42.695 39.581 39.581 39.581 39.581 39.581 40.723 39.67 40.723 39.67 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.787 40.725 39.787 40.725 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.787 40.723 39.7797 40.787 40.787 40.787 40.787 40.723 40.725 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755 40.755
Facies Crinkly laminated chert Crinkly laminated chert Crinkly lami	Sample D1	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 1 2 3 4 5 6 6 7 7 8 9 9 10 11 12 13 14 15 16 16 16 16 19 20 21 22 23 1 21 22 23 1 22 23 10 10 10 10 10 10 10 10 10 10	50733.42 A 81139.014 84247.965 81274.197 117812.291 104722.049 96482.040 99740.363 104722.049 94621.424 104722.049 9089.988 113871.145 765113.960 132448.332 110470.471 72087.414 110889.820 114866.137 100901.822 96074.261 163183.065 83369.268 93569.269 110334.95 A 69612.14	1235.26 Gaussian 1551.531 1553.306 1551.487 1551.487 1554.320 1554.486 1554.320 1554.486 1558.045 1558.045 1558.370 1547.4128 1558.370 1547.416 1558.370 1547.416 1558.910 1541.386 1558.910 1544.465 1544.465 1544.423 1550.28 Gaussian 0 1548.476 0 1548.76 0 0 0 0 0 0 0 0 0 0 0 0 0	181.68 (D3) / / 616.518 649.703 832.472 661.178 874.884 797.684 799.461 799.461 799.461 624.013 624.013 975.609 866.164 548.111 901.137 904.841 757.029 901.337 904.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 901.337 104.841 757.029 104.841 757.029 104.841 757.029 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.029 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.021 104.841 1057.029 104.841 1057.021 1057.021	210.14	227898.705 A 249454.102 231471.362 214316.034 235513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 277535.627 272692.790 340452.029 3427654.991 5424237.4659 299098.48 A 221388.94	1353.981 Lorentziar 0 1606.072 1605.348 1603.485 1603.485 1603.635 1603.635 1602.708 1604.009 1602.560 1603.163 1603.163 1603.482 1603.608 1604.877 1605.336 1604.877 1605.336 1604.833 1604.873 1604.851 1605.488 1603.59 Lorentziar 0 1604.50	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 4097.431 3750.230 5220.696 4521.064 3818.621 8898.087 4571.685 5174.524 4958.295 7757.978 4171.490 4599.600 (G) 3303.76	64.417 42.875 41.224 42.822 40.729 42.682 40.723 39.581 39.337 40.723 39.873 39.873 40.723 39.873 40.723 39.873 40.723 39.551 41.598 43.551 43.551 43.551 43.551 43.988 43.988 43.988 43.988 43.988 43.988 43.988 42.57 42.622 42.622 42.622 43.988 43.988 43.988 43.988 43.988 43.988 42.57 42.622 42.622 43.988 42.57 43.988 43.988 43.988 43.988 43.988 43.557 43.988 43.988 43.988 43.557 43.988 43.557 43.988 43.557 43.988 43.988 43.988 43.988 43.557 43.988 43.988 43.988 43.557 43.988 43.988 43.988 43.988 43.988 43.988 43.988 43.988 43.557 43.988 44.997 45.978 45.978 45.978 45.978 45.978 45.978 45.978 45.978 45.978 45.97888 45.97888 45.97888 45.97888888 45.97888888888888888888888888888888888888
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 Sample C9E	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 1 2 3 4 5 6 7 7 8 9 9 10 11 12 2 13 14 15 15 16 17 18 19 200 21 22 23 1 1 2 2 2 3 1 1 1 2 1 1 2 1 1 1 2 1 1 1 2 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76610.849 90889.988 113871.145 90889.988 113871.145 104702.471 72087.414 110489.820 110470.471 72087.414 110489.820 110470.471 72087.414 110889.820 110470.471 72087.414 110889.820 110470.471 72087.414 110889.820 110470.471 72087.414 110889.820 11037.421 114886.137 100901.822 96074.261 163183.065 89369.269 110334.95 110334.95 10034.95 1	1235.26 Gaussian	181.68 (D3) / / 649.703 832.472 661.178 874.884 797.880 799.461 799.461 799.461 799.464 799.464 799.464 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 1094.847 701.100 823.61 (D3) / 449.882 216.22	210.14	227898.705 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 277586.6786 326564.198 277586.080 340452.029 34052.029 340552.029 340555.029 340555.029 340555.029	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.635 1602.708 1602.708 1602.708 1603.336 1603.485 1603.485 1603.485 1603.485 1604.486 1602.529 1604.486 1605.336 1604.534 1605.348 1605.348 1605.488 1605.488 1605.488 1605.484 1605.485 1604.50 1599.56 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1604.50 1599.56 1605.348 1604.50 1599.56 1599.56 1599.	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 4521.064 4521.064 451.685 5174.524 4958.295 7257.978 4171.499 4599.60 6 (G) (J) 3303.76 1124.68	64.417 42.875 41.224 42.875 41.224 42.822 40.729 42.695 39.581 39.873 39.873 39.873 39.873 39.873 39.873 39.873 39.873 39.873 40.725 40.725 40.725 40.725 40.725 40.725 40.725 40.725
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 C9E C9E C9E	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 6 7 7 8 9 10 11 2 13 4 15 16 6 17 18 9 10 11 2 2 2 3 4 4 5 5 6 6 10 11 12 13 4 14 15 16 10 10 10 10 10 10 10 10 10 10	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 96482.040 994621.424 76401.849 90689.988 113871.145 76513.96 110470.471 72087.414 110889.820 114286.137 100901.822 96074.261 163183.065 89369.269 110334.95 A 6 9612.14 31187.12 21098.50 2 7608.63	1235.26 Gaussian 551.531 1553.306 1551.485 1551.485 1554.320 1554.486 1554.320 1554.486 1558.481 1558.0700 1544.128 1558.370 1547.316 1554.747 1555.271 1538.250 1541.386 1538.629 1554.932 1550.28 Gaussian ω 1548.76 1535.24 1535.	181.68 (D3) / / 649.703 832.472 661.178 874.884 797.638 799.461 799.461 799.461 799.461 700.319 820.680 624.013 975.609 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 1094.847 701.100 823.611 (D3) / 469.88 216.22 181.59 201.65	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233615.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 245066.786 326564.198 245066.786 326564.198 245066.786 2273586.080 340452.029 277558.680 340452.029 299098.48 221388.94 85978.57 97529.75 9	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485 1603.635 1603.635 1603.635 1603.635 1603.635 1603.73 1603.366 1603.367 1603.635 1603.635 1604.377 1603.608 1604.363 1604.353 1604.353 1604.353 1604.353 1604.353 1604.534 1605.336 1604.534 1605.335 Lorentziar ω 1604.50 1599.56 1601.57 1599.30	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8898.087 5174.524 4521.685 5174.524 4521.685 5174.529 4529.600 (G) / 3303.76 1124.68 1451.49 1246.28	64.417 42.875 41.224 42.825 40.729 42.695 39.581 40.723 39.581 40.723 39.873 39.9873 40.723 39.9873 40.723 39.9873 40.723 39.9873 40.723 39.9873 40.729 40.739
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 1 2 3 4 5 6 6 7 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 76401.849 94621.424 76401.849 9088.988 113871.145 104722.049 94621.424 76451.3960 132448.332 110470.471 12087.810 132448.332 110470.471 1089.820 114866.137 100901.822 96074.261 114886.137 100901.822 96074.261 114386.137 100901.822 96074.261 114386.137 100901.822 96074.261 114386.137 100901.822 96074.261 114386.137 100901.822 96074.261 114386.137 100901.822 96074.261 114386.137 100901.822 96074.261 11334.95 110334.95 110334.95 10034.95	1235.26 Gaussian	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 799.461 799.461 799.461 799.461 799.461 797.6662 634.839 700.319 820.660 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 1094.847 701.100 823.61 (D3) / 469.88 216.22 181.59 201.65 158.68	210.14	227898.705 249454.102 231471.362 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.045 193056.281 23056.281 251880.273 24506.786 326564.198 277536.267 272562.790 599404.068 273586.080 340452.029 327065.491 324356.080 340452.029 327065.491 32437.465 263474.699 299098.48 299098.48 299098.48 299098.48 299098.48 299098.48 29008.48 299098.48 29008.48 20008.48	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.396 1602.708 1602.708 1604.286 1603.173 1603.482 1603.482 1603.482 1603.484 1603.485 1604.486 1602.229 1603.853 1604.534 1604.534 1605.488 1605.488 1605.488 1605.485 1605.485 1605.485 1605.485 1605.485 1605.59 Lorentziar 0 1604.50 1599.56 1601.57 1599.30 1605.59	2358.814 1 (G) 1 (3) 1 (3) 1 (3) 1 (3) 1 (3) 1 (3) 1 (3) 1 (3) 1 (3) 1 (4) 1 (5) 1 (5)	64.417 42.875 41.224 42.825 40.723 39.581 40.723 39.873 39.873 39.873 39.873 39.873 39.873 40.723 40.723 44.025 40.729 44.965 39.728 42.039 42.039 42.57
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 Sample C9E C9E C9E C9E C9E C9E C9E C9E	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 6 7 7 7 7 8 9 9 10 11 12 13 14 15 16 16 17 17 18 19 20 21 22 23 3 4 5 5 6 6 6 1 1 2 5 5 6 6 6 1 1 2 5 5 6 6 6 1 1 1 2 5 5 6 6 6 1 1 1 1 1 1 1 1 1 1 1 1 1	50733.42 A 81139.014 84247.965 81274.197 117812.291 104722.049 96482.040 99740.363 104722.049 94621.424 76401.849 76401.849 104722.049 90889.988 113871.145 76513.96 110470.47 10470.47 10470.47 10489.48 110470.47 10489.48 110859.820 110859.820 110334.95 A 6 9612.14 31187.12 21098.50 27608.63 20427.94 39748.22	1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.487 1551.487 1554.801 1554.801 1554.801 1558.4801 1558.4801 1558.370 1544.128 1558.370 1544.128 1558.370 1547.471 1538.250 1541.386 1558.910 1551.196 1544.465 1554.741 1538.250 1544.465 1554.932 1550.28 Gaussian ω 1548.76 1538.24 1535.36 1515.01 1544.76 1538.26 1550.28 Gaussian ω 1544.76 1535.36 1515.01 1545.2.12	181.68 (D3) / 649.703 832.472 661.178 874.884 797.638 799.461 799.461 799.461 799.461 700.319 820.680 624.013 975.609 866.164 548.111 901.837 975.609 866.164 548.111 901.837 707.029 744.465 823.61 (D3) / 469.88 216.22 181.59 201.65 186.68	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233613.843 233663.586 221909.302 245483.988 230445.622 252903.046 139056.281 251880.273 245066.786 326564.198 245066.786 326564.198 2775356.267 272692.790 599404.068 277536.029 340452.029 340452.029 299098.48 A 221388.94 85978.57 97529.75 111436.05 75649.01 144272.61	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.396 1602.708 1602.708 1603.482 1603.482 1603.482 1603.482 1603.535 1604.877 1605.336 1604.537 1604.537 1604.538 1604.59 Lorentziar 0 1604.50 1599.56 1601.57 1599.30 1605.09 1605.09 1605.09 1605.45	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.639 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 4097.431 4097.431 3750.230 5220.696 4521.064 3818.621 898.607 4521.064 3818.621 898.607 4521.064 3818.621 4958.235 7257.978 4171.490 4599.60 1 (G) 1 2 3303.76 1124.688 1451.49 1246.28 1124.628 1	64.417 42.875 41.224 42.822 42.622 42.635 39.581 39.581 40.723 39.581 40.723 39.873 40.723 39.873 40.723 39.873 40.723 39.973 40.723 39.728 43.826 43.599 42.639 42.639 42.639 42.639 43.559 44.70 51.31 44.70 51.31 44.70 51.31 44.559 45.59 45
Facies Crinkly laminated chert	Sample D1 Sample C9E	Cloudy Cloudy CM microtexture Bitumen-like B	23 1 23 4 5 5 6 7 7 8 9 9 10 10 11 12 20 21 22 23 1 2 23 4 5 6 7 7 8 9 9 10 10 11 12 2 2 3 14 5 5 6 16 16 16 16 16 16 16 16 16	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 994621.424 90889.988 113871.145 765113.960 132448.332 1104722.049 90889.988 113871.145 76513.960 132448.332 100472.0471 72087.414 110889.820 114866.137 100901.822 96074.261 163183.065 89359.265 96074.261 163183.055 89359.265 96072.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979	1235.26 Gaussian 1551.531 1553.306 1551.487 1551.487 1554.320 1554.320 1554.320 1554.486 1558.040 1558.047 1558.047 1558.277 1557.316 1558.474 1558.277 1557.316 1558.196 1544.465 1558.628 1550.288 Gaussian 1550.288 1550.28	181.68 (D3) / 616.518 649.703 832.472 661.178 832.472 661.178 874.884 797.680 799.461 799.461 799.461 634.839 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 901.137 904.841 757.029 744.465 1094.847 701.100 823.61 094.841 757.029 744.465 1094.847 701.100 823.61 094.841 757.029 744.465 1094.847 701.100 823.61 094.847 701.100 823.61 094.847 701.100 823.61 094.847 701.100 823.61 094.847 701.100 823.61 1094.847 701.100 823.61 1094.847 701.029 701.029 701.029 701.029 701.029 701.029 701.029 702.029 702.029 702.029 702.029 702.029 702.029 703.029 703.029 703.029 703.029 704.029 705.029	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 277535.6267 272692.790 327065.491 524237.465 239098.48 A 221388.94 85978.57 97529.75 111436.05 75649.01 144272.61 388676.928 38232.394	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.435 1603.435 1603.435 1602.708 1602.708 1602.500 1603.432 1603.432 1603.432 1603.432 1603.485 1604.534 1605.396 1604.534 1605.59 Lorentziar 0 1605.09 1605.09 1605.45	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 4058.699 4521.064 3818.621 4571.685 5174.524 5174.525 5174.524 5	64.417 42.875 41.224 42.822 40.729 42.695 39.581 40.723 39.873 39.873 39.873 39.873 39.873 40.723 39.9873 40.723 39.9873 40.723 39.9873 40.723 39.9873 40.723 39.9873 43.926 43.926 43.926 43.988 44.965 39.728 42.639 43.551 43.988 43.988 42.639 42.639 42.639 42.639 42.639 43.551 43.988 43.551 43.988 42.639 42.639 42.639 42.639 43.551 43.988 42.639 42.639 42.639 42.639 42.639 43.551 43.988 43.551 43.988 42.639 42.57 42.639 42.57 44.965 53.51 42.639 42.57 44.965 53.51 42.639 42.57 44.965 53.51 44.965 42.639 42.57 44.965 45.965 4
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 Sample C9E	Cloudy Cloudy CM microtexture Bitumen-like B	23 1 2 3 4 5 6 7 7 8 9 100 211 223 1 233 4 1 2 233 1 2 3 4 5 6 7 8 9 9 100 211 2 2 3 4 5 6 7 8 9 9 100 211 2 2 3 4 5 6 7 8 9 9 100 211 2 2 3 4 5 6 7 8 8 9 9 100 100 100 100 100 100 10	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76601.849 90889.988 113871.145 90889.988 113871.145 104702.471 72087.414 110889.820 110470.471 72087.414 110489.820 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10337.979 10337.979	1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.485 1554.320 1554.801 1554.801 1554.801 1554.801 1558.0700 1544.128 1558.047 1558.2471 1558.25271 1538.250 1547.365 1558.910 1554.321 1558.932 1558.932 1554.932 1550.28 Gaussian ω 1545.64 1515.01 1545.46 1515.01 1545.46 1515.01 1542.728 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648 1555.648	181.68 (D3) / / 649.703 832.472 661.178 874.884 797.880 799.461 766.662 634.839 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 1094.847 701.100 823.611 (D3) / 469.847 701.100 823.61 15.9 21.159 201.65 15.668 82.159 201.65 15.688 301.93 852.732 92.951 293.811	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 2251880.273 245066.786 326564.198 245066.786 326564.198 245066.786 326564.198 2775386.080 340452.029 39404.068 273586.080 340452.029 39404.068 243086.491 242084.49 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 24308.44	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485 1603.635 1602.708 1604.520 1603.485 1603.635 1602.708 1602.708 1603.635 1603.636 1603.462 1603.462 1603.463 1603.635 1604.877 1605.386 1604.534 1604.534 1604.534 1604.534 1605.485 1604.50 1599.56 1605.09 1605.45 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.338	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8898.087 4571.685 5174.524 4958.295 7257.978 4171.490 4599.60 (G) / 3303.76 1124.68 1451.49 1264.28 1125.37 2114.72 5881.250 618.826 1505.781	64.417 42.875 41.224 42.825 41.224 40.729 42.695 39.581 40.723 39.873 39.873 39.873 39.873 39.873 39.873 39.873 39.873 40.723 40.723 40.723 39.873 40.723 40.724 40.729 40.725 40.729 40.725 40.755 40.7
Facies Crinkly laminated chert Crinkly laminated chert Massive black chert Massive black chert Massive black chert Massive black chert	Sample D1	Cloudy Cloudy CM microtexture Bitumen-like B	23 1 1 2 3 4 5 6 7 7 8 9 9 100 111 122 131 14 155 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 16 17 17 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 16 17 17 16 17 17 16 17 17 17 17 17 17 17 17 17 17	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 76401.849 94621.424 76401.849 9088.988 113871.145 104722.049 94621.424 76451.3960 132448.332 110470.471 12089.820 114866.137 100901.822 96074.261 114886.137 100901.822 96074.261 114885.137 100901.822 96074.261 114885.137 100901.822 96074.261 114885.137 100901.822 96074.261 114885.137 100901.822 96074.261 11485.137 100901.822 96074.261 11485.137 100901.822 96074.261 11485.137 100901.822 96074.261 11485.137 100901.822 96074.261 10334.95 10334.95 10334.95 1034.95 1	1235.26 Gaussian 1551.531 1553.306 1551.485 1551.485 1554.320 1554.486 1554.801 1558.4747 1558.370 1547.316 1558.370 1547.316 1558.370 1547.316 1558.370 1547.316 1547.316 1558.370 1547.316 1547.316 1547.316 1547.316 1548.476 1535.24 1550.28 Gaussian 0 0 1548.76 1535.24 1550.28 Gaussian 1550.28 1550.2	181.68 (D3) / / 616.518 649.703 832.472 661.178 874.884 797.684 799.461 799.461 799.461 799.461 624.013 975.609 866.164 624.013 975.609 866.164 901.137 904.841 757.029 901.841 757.029 901.841 757.029 901.841 757.029 901.841 757.029 901.85 186.68 866.164 1094.847 701.100 823.61 091.847 701.100 823.61 091.847 701.100 823.61 1094.847 701.100 823.61 823.61 824.83 825.732 924.831 292.831 292.831 292.734 924.734 924.734 925.734	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 23513.843 237663.586 221909.302 245483.988 230445.622 245483.988 230445.622 245483.988 245483.988 245483.988 245483.046 252903.046 326564.198 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 2775356.080 284 221388.94 85978.57 97522.75 111436.05 75649.01 144272.61 388676.928 38232.394 93359.438 143880.758	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.635 1603.396 1602.708 1602.708 1603.73 1603.482 1603.668 1603.163 1603.482 1603.668 1604.877 1605.336 1604.877 1605.336 1604.50 1599.56 1601.57 1599.30 1605.485 1603.553 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.385 1605.485 1603.385 1605.485 1603.385 1605.485 1605.485 1603.385 1605.485 1603.385 1605.485 1603.385 1605.485 1603.485 1604.217	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 4097.431 4097.431 4097.431 3750.230 5220.696 4521.064 3818.621 4521.064 3818.621 5174.524 4598.295 7257.978 4171.490 4599.600 (G) (G) (G) (G) (G) (G) (G) (G)	64.417 42.875 41.224 42.825 40.723 39.337 40.723 39.873 39.873 39.873 39.873 39.873 39.873 40.723 40.723 44.025 40.729 44.965 39.728 42.039 42.57
Facies Crinkly laminated chert Crinkly laminated chert	Sample D1 Sample C9E	Cloudy Cl	23 1 2 3 4 5 6 7 7 8 9 9 10 0 11 12 3 14 15 6 7 7 8 9 9 10 0 11 12 13 14 15 16 17 18 19 20 20 20 20 20 20 20 20 20 20	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76601.849 90889.988 113871.145 90889.988 113871.145 104702.471 72087.414 110889.820 110470.471 72087.414 110489.820 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10337.979 10337.979	1235.26 Gaussian 1551.531 1553.306 1551.837 1554.820 1554.820 1554.801 1554.801 1554.801 1554.801 1558.047 1555.047 1555.271 1538.250 1547.47 1558.247 1538.250 1541.386 1538.629 1544.865 1538.629 1554.932 1554.932 1554.932 1554.932 1552.28 Gaussian ω 1545.64 1515.01 1545.64 1545.64 1542.728 1555.648	181.68 (D3) / / 649.703 832.472 661.178 874.884 797.880 799.461 766.662 634.839 700.319 820.680 624.013 975.609 866.164 548.111 901.137 904.841 757.029 744.465 1094.847 701.100 823.611 (D3) / 469.847 701.100 823.61 15.9 21.159 201.65 15.668 82.159 201.65 15.688 301.93 852.732 92.951 293.811	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 283513.843 237663.586 221909.302 245483.988 230445.622 252903.046 193056.281 2251880.273 245066.786 326564.198 245066.786 326564.198 245066.786 326564.198 2775386.080 340452.029 39404.068 273586.080 340452.029 39404.068 243086.491 242084.49 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 243086.491 24308.44	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485 1603.635 1602.708 1604.520 1603.485 1603.635 1602.708 1602.708 1603.635 1603.636 1603.462 1603.462 1603.463 1603.635 1604.877 1605.386 1604.534 1604.534 1604.534 1604.534 1605.485 1604.50 1599.56 1605.09 1605.45 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.553 1605.455 1603.338	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8898.087 4571.685 5174.524 4958.295 7257.978 4171.490 4599.60 (G) / 3303.76 1124.68 1451.49 1264.28 1125.37 2114.72 5881.250 618.826 1505.781	64.417 42.875 41.224 42.825 41.224 40.729 42.695 39.581 40.723 39.873 39.873 39.873 39.873 39.873 39.873 39.873 39.873 40.723 40.723 40.723 39.873 40.723 40.724 40.729 40.725 40.729 40.725 40.755 40.7
Facies Crinkly laminated chert Crinkly laminated chert Massive black chert	Sample D1 Sample C9E C9E </td <td>Cloudy CM microtexture Bitumen-like Bitumen-</td> <td>23 1 2 3 4 5 6 7 8 9 10 11 122 23 14 15 16 17 18 19 20 21 22 23 4 5 6 7 8 9 1 22 23 4 5 6 7 8 9 10 12 23 4 5 6 7 8 9 10 11 12 13 </td> <td>50733.42 A 81139.014 84247.965 81274.197 117812.291 117812.291 96482.040 99740.363 104722.049 94621.424 90889.988 113871.145 76513.968 1132448.332 104702.471 172087.414 10859.826 114886.137 100901.822 96074.261 163183.065 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 46439.656 44166.430 56312.058 56312.</td> <td>1235.26 Gaussian ω 1551.531 1553.306 1551.487 1551.487 1551.487 1551.487 1551.487 1554.801 1554.801 1554.801 1558.474 1558.370 154.128 1558.370 154.747 1558.271 1538.250 1541.386 1554.741 1538.250 1541.386 1554.3810 1551.196 1544.465 1538.629 1550.28 Gaussian 0 0 154.383.36 1515.01 154.461 154.35.36 1515.01 154.472 1555.648 1545.344 1545.041 1545.344 1540.45</td> <td>181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)</td> <td>210.14</td> <td>227898.705 A 249454.102 231471.362 309154.216 214316.034 233613.843 233663.586 221909.302 245483.988 230445.622 245483.988 230445.622 245483.988 245046.786 225290.3046 133056.281 245066.786 226564.198 245066.786 2277536.080 340452.029 327065.491 524237.465 2273586.080 340452.029 327065.491 524237.465 2273586.080 340452.029 327065.491 524237.465 229098.48 A 221388.94 85978.57 97522.75 111436.05 75649.01 144272.61 388676.928 38232.394 93359.438 143880.758 154691.095 192282.549</td> <td>1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.396 1602.708 1602.708 1602.708 1603.482 1603.482 1603.482 1603.482 1603.482 1604.537 1604.537 1604.537 1604.538 1604.539 Lorentziar 0 1605.09 1605.09 1605.09 1605.09 1605.45 1603.482 1603.538 1605.09 1605.45 1603.388 1604.877 1605.388 1604.50 1599.56 1601.57 1599.30 1605.485 1603.388 1604.878 1604.856 1604.85</td> <td>2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8988.687 4571.685 5174.524 4958.295 7257.978 4599.600 4599.600 124.688 1124.688 1471.490 4599.600 124.628 1125.37 2114.72 5881.250 618.266 1505.781 2055.7917 2341.484 2950.033 2108.69</td> <td>64.417 42.875 41.224 42.822 42.622 42.632 42.632 42.632 43.531 40.723 39.581 39.337 40.723 39.873 39.973 39.973 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.728 43.3967 43.597 43.987 43.987 43.987 43.987 43.987 43.993 42.039 42.039 42.039 42.57 43.987 42.039 42.037 43.988 43.988 43.987 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 45.993 46.94 46</td>	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 7 8 9 10 11 122 23 14 15 16 17 18 19 20 21 22 23 4 5 6 7 8 9 1 22 23 4 5 6 7 8 9 10 12 23 4 5 6 7 8 9 10 11 12 13	50733.42 A 81139.014 84247.965 81274.197 117812.291 117812.291 96482.040 99740.363 104722.049 94621.424 90889.988 113871.145 76513.968 1132448.332 104702.471 172087.414 10859.826 114886.137 100901.822 96074.261 163183.065 A 6 9612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 46439.656 44166.430 56312.058 56312.	1235.26 Gaussian ω 1551.531 1553.306 1551.487 1551.487 1551.487 1551.487 1551.487 1554.801 1554.801 1554.801 1558.474 1558.370 154.128 1558.370 154.747 1558.271 1538.250 1541.386 1554.741 1538.250 1541.386 1554.3810 1551.196 1544.465 1538.629 1550.28 Gaussian 0 0 154.383.36 1515.01 154.461 154.35.36 1515.01 154.472 1555.648 1545.344 1545.041 1545.344 1540.45	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233613.843 233663.586 221909.302 245483.988 230445.622 245483.988 230445.622 245483.988 245046.786 225290.3046 133056.281 245066.786 226564.198 245066.786 2277536.080 340452.029 327065.491 524237.465 2273586.080 340452.029 327065.491 524237.465 2273586.080 340452.029 327065.491 524237.465 229098.48 A 221388.94 85978.57 97522.75 111436.05 75649.01 144272.61 388676.928 38232.394 93359.438 143880.758 154691.095 192282.549	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.396 1602.708 1602.708 1602.708 1603.482 1603.482 1603.482 1603.482 1603.482 1604.537 1604.537 1604.537 1604.538 1604.539 Lorentziar 0 1605.09 1605.09 1605.09 1605.09 1605.45 1603.482 1603.538 1605.09 1605.45 1603.388 1604.877 1605.388 1604.50 1599.56 1601.57 1599.30 1605.485 1603.388 1604.878 1604.856 1604.85	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8988.687 4571.685 5174.524 4958.295 7257.978 4599.600 4599.600 124.688 1124.688 1471.490 4599.600 124.628 1125.37 2114.72 5881.250 618.266 1505.781 2055.7917 2341.484 2950.033 2108.69	64.417 42.875 41.224 42.822 42.622 42.632 42.632 42.632 43.531 40.723 39.581 39.337 40.723 39.873 39.973 39.973 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.728 43.3967 43.597 43.987 43.987 43.987 43.987 43.987 43.993 42.039 42.039 42.039 42.57 43.987 42.039 42.037 43.988 43.988 43.987 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 44.007 45.993 46.94 46
Facies Crinkly laminated chert Crinkly laminated chert Massive black chert	Sample D1 Sample C9E C9E </td <td>Cloudy Cloudy Cl</td> <td>23 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 22 23 4 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 10 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 11 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 10 11 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 10 12 12 22 23 3 4 4 4 5 5 6 7 7 7 8 9 9 10 11 12 12 12 12 12 12 12 12 12</td> <td>50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 96482.049 94621.424 94621.424 94621.424 90689.388 113871.145 76513.948 113871.145 76513.948 110470.471 110489.820 110472.471 110489.820 110472.471 114886.137 100901.822 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 11352.992 4439.656 44166.430 56312.058 45188.85</td> <td>1235.26 Gaussian 551.531 1553.306 1551.837 1554.801 1554.801 1554.801 1554.801 1554.801 1554.801 1558.0700 1544.128 1558.910 1558.271 1538.220 1547.316 1558.910 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1555.244 1535.244 1535.24 1535.24 1555.648 1515.01 1544.768 1515.01 1544.768 1515.01 1545.456 1545.466 1545.466 1545.467 1547.476 15</td> <td>181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)</td> <td>210.14</td> <td>227898.705</td> <td>1353.981 Lorentziar 0 1606.072 1605.348 1603.635 1603.485 1603.485 1603.336 1602.708 1602.708 1603.336 1603.336 1603.485 1603.485 1603.485 1603.485 1604.584 1605.348 1605.348 1605.485 1604.50 1599.56 1604.50 1599.56 1603.553 1604.553 1604.50 1599.56 1603.553 1605.455 1603.353 1605.455 1603.353 1605.455 1603.353 1605.455 1603.358 1603.388 1605.485 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1605.48</td> <td>2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3742.231 4005.603 3285.541 4097.431 3750.230 5220.696 4521.064 4521.064 4521.064 4521.064 4521.064 4571.685 5174.524 4958.926 (G) (G) (G) (G) (G) (C) (C) (C) (C) (C) (C) (C) (C</td> <td>64.417 42.875 41.224 42.875 41.224 40.729 42.695 39.581 40.723 39.873 39.873 39.873 39.873 39.873 39.873 39.873 40.725 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.723 40.725 40.755</td>	Cloudy Cl	23 1 2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 22 23 4 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 13 14 15 16 6 7 7 8 9 9 10 11 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 10 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 11 11 12 22 23 3 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 11 11 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 10 11 12 12 22 23 3 4 4 4 5 5 6 6 7 7 8 9 9 10 12 12 22 23 3 4 4 4 5 5 6 7 7 7 8 9 9 10 11 12 12 12 12 12 12 12 12 12	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 96482.049 94621.424 94621.424 94621.424 90689.388 113871.145 76513.948 113871.145 76513.948 110470.471 110489.820 110472.471 110489.820 110472.471 114886.137 100901.822 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 11352.992 4439.656 44166.430 56312.058 45188.85	1235.26 Gaussian 551.531 1553.306 1551.837 1554.801 1554.801 1554.801 1554.801 1554.801 1554.801 1558.0700 1544.128 1558.910 1558.271 1538.220 1547.316 1558.910 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1554.932 1555.244 1535.244 1535.24 1535.24 1555.648 1515.01 1544.768 1515.01 1544.768 1515.01 1545.456 1545.466 1545.466 1545.467 1547.476 15	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705	1353.981 Lorentziar 0 1606.072 1605.348 1603.635 1603.485 1603.485 1603.336 1602.708 1602.708 1603.336 1603.336 1603.485 1603.485 1603.485 1603.485 1604.584 1605.348 1605.348 1605.485 1604.50 1599.56 1604.50 1599.56 1603.553 1604.553 1604.50 1599.56 1603.553 1605.455 1603.353 1605.455 1603.353 1605.455 1603.353 1605.455 1603.358 1603.388 1605.485 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 1603.388 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Facies Crinkly laminated chert Crinkly laminated chert Massive black chert	Sample D1 Sample C9E C9E </td <td>Cloudy CM microtexture Bitumen-like Bitumen-</td> <td>23 1 2 3 4 5 6 7 7 8 9 11 122 23 14 15 16 17 18 19 20 21 22 23 4 5 6 7 8 9 11 122 23 4 5 6 7 8 9 11 12 13 14 15</td> <td>50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 99740.363 104722.049 94621.424 9089.988 113871.145 176513.960 132448.332 104702.471 72087.414 10889.988 113871.145 114866.137 100901.822 96074.261 163183.065 910334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 94639.656 44166.430 5612.058 45186.85 73168.431 54644.138</td> <td>1235.26 Gaussian 1551.531 1553.306 1551.4837 1551.4837 1551.4837 1554.320 1554.320 1554.320 1554.321 1558.045 1558.370 1558.370 1547.316 1558.370 1557.316 1558.370 1551.196 1544.465 1538.629 1554.386 1558.478 1550.288 Gaussian 554.486 1544.465 1534.328 1550.288 Gaussian 1545.288 1550.288 1544.465 1544.728 1555.648 1545.466 1545.</td> <td>181.68 (D3) (D3) (D3) (D3) (D3) (D4)</td> <td>210.14</td> <td>227898.705 A 249454.102 231471.362 309154.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 277535.6267 272692.790 327065.491 52437.465 221388.94 85978.57 97529.75 111436.05 75649.01 144272.61 388275.294 93359.438 154691.095 192282.549 145861.94 388753.272</td> <td>1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.336 1602.708 1602.708 1602.708 1604.536 1603.163 1603.482 1603.608 1603.638 1604.877 1605.336 1604.877 1605.336 1604.537 1604.537 1604.537 1604.537 1605.488 1603.559 Lorentziar 0 1605.455 1603.485 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1604.856 1604.857 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.338 1605.084 1605.084 1605.381 1605.3</td> <td>2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 33285.541 4097.431 3750.230 5220.696 4521.064 3818.621 4058.697 4571.685 5174.524 4958.295 7257.978 4171.490 4599.60 10 124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1125.37 2114.72 5881.250 618.266 1505.781 2055.781 2</td> <td>64.417 42.875 41.224 42.822 42.622 42.635 39.581 39.581 39.733 39.873 39.873 39.873 39.873 39.973 39.973 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.728 43.020 43.551 43.987 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 43.987 44.007 44.967 44.967 44.967 44.967 44.967 44.994 45.994 45.994 45.992 45.991</td>	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 7 7 8 9 11 122 23 14 15 16 17 18 19 20 21 22 23 4 5 6 7 8 9 11 122 23 4 5 6 7 8 9 11 12 13 14 15	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 99740.363 104722.049 94621.424 9089.988 113871.145 176513.960 132448.332 104702.471 72087.414 10889.988 113871.145 114866.137 100901.822 96074.261 163183.065 910334.95 A 6 9612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 94639.656 44166.430 5612.058 45186.85 73168.431 54644.138	1235.26 Gaussian 1551.531 1553.306 1551.4837 1551.4837 1551.4837 1554.320 1554.320 1554.320 1554.321 1558.045 1558.370 1558.370 1547.316 1558.370 1557.316 1558.370 1551.196 1544.465 1538.629 1554.386 1558.478 1550.288 Gaussian 554.486 1544.465 1534.328 1550.288 Gaussian 1545.288 1550.288 1544.465 1544.728 1555.648 1545.466 1545.	181.68 (D3) (D3) (D3) (D3) (D3) (D4)	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233663.586 221909.302 245483.988 230445.622 252903.046 193056.281 251880.273 245066.786 326564.198 326564.198 277535.6267 272692.790 327065.491 52437.465 221388.94 85978.57 97529.75 111436.05 75649.01 144272.61 388275.294 93359.438 154691.095 192282.549 145861.94 388753.272	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.336 1602.708 1602.708 1602.708 1604.536 1603.163 1603.482 1603.608 1603.638 1604.877 1605.336 1604.877 1605.336 1604.537 1604.537 1604.537 1604.537 1605.488 1603.559 Lorentziar 0 1605.455 1603.485 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.455 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1604.856 1604.857 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.485 1605.338 1605.084 1605.084 1605.381 1605.3	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 33285.541 4097.431 3750.230 5220.696 4521.064 3818.621 4058.697 4571.685 5174.524 4958.295 7257.978 4171.490 4599.60 10 124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1124.688 1125.37 2114.72 5881.250 618.266 1505.781 2055.781 2	64.417 42.875 41.224 42.822 42.622 42.635 39.581 39.581 39.733 39.873 39.873 39.873 39.873 39.973 39.973 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.728 43.020 43.551 43.987 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 42.039 43.987 44.007 44.967 44.967 44.967 44.967 44.967 44.994 45.994 45.994 45.992 45.991
Facies Crinkly laminated chert Massive black chert Mas	Sample D1	Cloudy Cloudy CM microtexture Bitumen-like B	23 1 23 4 5 6 6 7 7 8 9 9 0 111 12 12 23 14 15 16 6 7 7 8 9 9 0 111 12 12 22 23 4 5 6 6 7 7 8 9 9 10 111 12 12 22 23 4 5 6 7 7 8 9 9 10 111 12 12 22 23 23 4 5 6 7 7 8 9 9 10 111 12 12 22 23 4 5 6 7 7 8 9 9 10 111 12 12 22 23 4 5 6 7 8 9 9 10 111 12 12 22 23 4 5 6 6 7 7 8 9 10 111 12 12 22 23 4 5 6 6 7 7 8 9 9 10 111 12 22 23 4 5 6 6 7 7 8 9 9 10 111 12 22 23 3 4 5 6 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 7 7 8 9 9 10 112 12 22 23 3 4 5 6 7 7 8 9 9 10 112 112 12 22 23 3 14 14 5 15 16 7 7 7 8 12 12 12 12 12 12 12 12 12 12	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 117812.291 96482.040 99740.363 104722.049 94621.424 9089.988 113871.145 765113.960 132448.332 104702.471 72087.414 110879.829 110470.471 72087.414 10899.988 113871.45 76513.960 132448.332 96074.261 163183.065 893569.260 110334.955 A 69612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 46439.656 44166.430 56312.058 45188.431 54644.138 22972.160	1235.26 Gaussian 1551.531 1553.306 1551.485 1554.320 1554.486 1554.486 1554.801 1558.4747 1558.370 1544.465 1554.747 1558.370 1547.316 1547.316 1547.316 1547.316 1547.316 1547.316 1547.316 1548.76 1538.629 1550.28 Gaussian 0 0 1548.76 1535.24 1550.28 Gaussian 1548.76 1535.24 1550.28 Gaussian 1548.76 1535.24 1550.28 Gaussian 1548.76 1535.24 1550.28 1548.76 1535.24 1550.28	181.68 (D3) / 616.518 649.703 832.472 661.178 874.884 797.685 874.884 797.687 799.461 799.461 624.013 820.680 624.013 975.609 866.164 548.8111 901.137 704.465 1094.841 757.029 901.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 001.837 701.100 823.61 638.322 224.26.080 156.175 374.275 844.275 845.275 84	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233663.586 221909.302 245483.988 230445.622 245483.988 230445.622 252903.046 193056.281 25180.6786 2252903.046 193056.281 25180.6786 2252903.046 2252903.046 2252903.046 2252903.046 2252903.046 2252903.046 2252903.046 2252903.046 225292.75 111436.05 75649.01 144272.61 38676.928 32522.394 93359.438 154691.092 145661.94 32522.391 145661.94 32522.391 32505.491	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.635 1602.708 1602.508 1602.508 1603.173 1603.482 1603.608 1604.877 1605.336 1604.877 1605.336 1604.537 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1604.5376 1605.485 1603.553 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.353 1605.485 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1603.351 1605.840 1605.84	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.431 4097.685 5174.524 4521.064 3818.621 5174.524 4599.600 4599.600 (G) (G) (G) 205.097 2341.482 1246.28 1246.28 1245.37 2114.72 5881.250 618.826 1505.781 2055.097 2341.484 4280.033 2108.69 2943.444 1289.016 2541.982	64.417 42.875 41.224 42.825 42.825 42.822 42.625 42.625 43.938 40.723 39.581 39.581 39.337 40.723 39.581 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.783 43.020 39.67 43.020 39.783 43.025 43.025 43.988 44.965 39.728 42.650 44.060 44.061 41.778 41.728 41.728 41.728 41.200 42.651 41.200 41.778 41.200 41.778 41.200 41.778 41.200 41.778 41.200 41.205 41.200 41.778 41.200 41.778 41.200 41.205
Facies Crinkly laminated chert Massive black chert	Sample D1 Sample C9E C9E </td <td>Cloudy CM microtexture Bitumen-like Bitumen-</td> <td>23 1 2 3 4 5 6 7 7 8 9 9 10 11 12 2 3 14 1 12 2 3 14 1 12 2 2 3 14 1 12 2 2 3 14 1 1 12 2 3 14 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1</td> <td>50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 96482.1424 76401.849 9689.988 113871.145 76513.96074.261 104702.7647 110889.820 110470.471 110489.820 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 3187.12 21098.50 27608.63 20427.94 3177.979 1352.992 46439.656 12.14 3187.12 21098.50 27608.63 20427.94 31752.992 46439.656 41566.430 56312.058 573168.431 54644.138 22972.160 45086.031</td> <td>1235.26 Gaussian ω 1551.531 1553.306 1551.487 1551.487 1554.801 1554.801 1554.801 1558.4801 1558.370 1544.128 1558.370 1544.128 1558.370 1544.128 1558.370 1544.128 1554.741 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1544.465 1544.465 1545.26 Gaussian ω 1544.728 1555.648 1543.4151 1543.4151 1543.4151 1543.4151 1543.4151 1543.41</td> <td>181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)</td> <td>210.14</td> <td>227898.705</td> <td>1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.485 1603.396 1604.520 1603.485 1603.635 1603.73 1603.462 1603.73 1603.482 1603.481 1603.482 1604.877 1604.877 1604.353 1604.487 1604.548 1605.396 Lorentziar 0 1604.50 1599.56 1605.499 1605.499 1605.491 1605.491 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.6445 1603.381 1605.644 1603.381<!--</td--><td>2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 14095.625 7257.978 8174.529 4595.607 (G) (G) (G) (G) (C) (C) (C) (C) (C) (C) (C) (C</td><td>64.417 42.875 41.224 42.875 42.822 42.695 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.781 40.723 39.781 40.797 40.725 39.781 40.727 40.725 40.727 40.725</td></td>	Cloudy CM microtexture Bitumen-like Bitumen-	23 1 2 3 4 5 6 7 7 8 9 9 10 11 12 2 3 14 1 12 2 3 14 1 12 2 2 3 14 1 12 2 2 3 14 1 1 12 2 3 14 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 96482.1424 76401.849 9689.988 113871.145 76513.96074.261 104702.7647 110889.820 110470.471 110489.820 96074.261 163183.065 89369.269 110334.95 A 69612.14 31187.12 21098.50 27608.63 20427.94 3187.12 21098.50 27608.63 20427.94 3177.979 1352.992 46439.656 12.14 3187.12 21098.50 27608.63 20427.94 31752.992 46439.656 41566.430 56312.058 573168.431 54644.138 22972.160 45086.031	1235.26 Gaussian ω 1551.531 1553.306 1551.487 1551.487 1554.801 1554.801 1554.801 1558.4801 1558.370 1544.128 1558.370 1544.128 1558.370 1544.128 1558.370 1544.128 1554.741 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1538.629 1544.465 1544.465 1545.26 Gaussian ω 1544.728 1555.648 1543.4151 1543.4151 1543.4151 1543.4151 1543.4151 1543.41	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.485 1603.485 1603.485 1603.485 1603.396 1604.520 1603.485 1603.635 1603.73 1603.462 1603.73 1603.482 1603.481 1603.482 1604.877 1604.877 1604.353 1604.487 1604.548 1605.396 Lorentziar 0 1604.50 1599.56 1605.499 1605.499 1605.491 1605.491 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.485 1603.338 1605.6445 1603.381 1605.644 1603.381 </td <td>2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 14095.625 7257.978 8174.529 4595.607 (G) (G) (G) (G) (C) (C) (C) (C) (C) (C) (C) (C</td> <td>64.417 42.875 41.224 42.875 42.822 42.695 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.781 40.723 39.781 40.797 40.725 39.781 40.727 40.725 40.727 40.725</td>	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 14095.625 7257.978 8174.529 4595.607 (G) (G) (G) (G) (C) (C) (C) (C) (C) (C) (C) (C	64.417 42.875 41.224 42.875 42.822 42.695 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.581 40.723 39.781 40.723 39.781 40.797 40.725 39.781 40.727 40.725 40.727 40.725
Facies Crinkly laminated chert Massive black chert Mas	Sample D1	Cloudy Cl	23 1 1 2 3 4 5 6 7 7 8 9 9 10 11 12 3 14 15 6 7 7 8 9 9 10 11 12 23 14 15 16 16 17 18 19 20 21 22 23 4 4 4 5 6 7 8 9 9 10 11 12 13 14 15 16 6 7 7 8 9 9 10 11 12 13 14 15 16 16 16 17 18 16 16 16 17 18 18 19 20 21 22 22 23 1 11 11 12 21 22 22 23 14 4 15 16 16 17 18 18 19 20 21 22 22 23 10 11 11 12 21 22 23 14 4 4 4 4 4 4 4 4 4 15 16 6 7 8 9 9 10 11 11 12 22 22 23 3 4 4 4 4 4 4 4 15 16 6 7 7 8 9 9 10 21 12 22 23 3 4 4 4 4 4 4 4 4 4 4 15 16 6 7 7 8 9 9 10 21 12 23 3 4 4 4 4 4 15 16 17 8 10 10 11 11 12 12 22 23 3 4 4 4 4 15 16 16 17 18 18 18 18 18 18 18 18 18 18	50733.42 A 81139.014 84247.965 110234.967 117812.291 96482.049 99642.049 94621.424 766401.849 94621.424 766401.849 94621.424 76401.849 94621.424 76401.849 94621.424 76401.849 94621.424 104722.049 104722.049 104722.049 104722.049 10472.649 10472.649 10472.649 10472.649 10472.649 10472.649 10334.95 10344.138 10444.138 10444.138 10444.138 10444.138 10464.030	1235.26 Gaussian ω 1551.531 1551.837 1551.837 1551.837 1551.837 1554.801 1554.801 1554.801 1554.801 1554.801 1558.947 1558.947 1558.947 1558.947 1558.947 1558.271 1558.271 1538.629 1544.128 1558.910 1551.196 1544.465 1538.629 1544.465 1538.629 1544.74 1538.629 1544.76 1535.24 1535.24 1535.24 1535.24 1535.24 1535.24 1535.48 1545.493 1545.493 1545.493 1545.494 1555.648 1545.491 1545.491 1545.491	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705	1353.981 Lorentziar 0 1606.072 1605.348 1603.635 1603.485 1603.485 1603.396 1602.708 1602.708 1603.356 1603.356 1603.165 1603.482 1603.682 1603.533 1604.486 1603.533 1604.534 1605.548 1605.458 1603.553 1604.57 1599.56 1605.458 1603.553 1604.57 1599.56 1603.553 1604.57 1599.56 1603.553 1605.455 1603.358 1605.455 1603.358 1605.696 1603.359 1605.696 1605.69	2358.814 / / / / / / / / / / / / /	64.417 42.875 41.224 42.875 41.224 40.729 42.695 39.581 39.873 39.873 39.873 39.873 39.873 39.873 40.725 40.723 40.725 40.7
Facies Crinkly laminated chert Massive black chert	Sample D1 C9E C9E C9E C9E C9E C9E <t< td=""><td>Cloudy Cloudy Cl</td><td>23 1 2 3 4 5 6 7 8 9 100 211 223 3 14 15 16 17 223 3 4 5 6 7 8 90 211 223 3 4 5 6 7 8 90 112 233 4 5 6 7 8 9 100 211 12 33 14 15 16 17 18 9 <!--</td--><td>50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 96482.049 94621.424 104722.049 94621.424 104722.049 94621.424 10472.049 90889.988 113871.145 10470.471 72087.414 110889.820 10270.471 172087.414 110889.820 10247.94 96074.261 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 970974.977 97094.977</td><td>1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.485 1554.801 1554.801 1554.801 1554.801 1558.4320 1558.4320 1558.4321 1558.4321 1558.4321 1558.4321 1558.2471 1558.25271 1538.250 1547.47 1558.25271 1538.250 1547.475 1558.4465 1558.25271 1538.250 1547.475 1558.431 1558.25271 1538.250 1547.475 1558.431 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271</td></td></t<> <td>181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)</td> <td>210.14</td> <td>227898.705</td> <td>1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.452 1603.635 1603.635 1603.635 1603.635 1603.635 1603.636 1603.636 1603.637 1603.638 1603.638 1603.638 1603.638 1604.877 1605.386 1604.534 1604.534 1604.534 1604.534 1605.485 1605.485 1603.553 1604.501 1599.56 1605.455 1603.553 1605.455 1603.338 1604.217 1605.455 1603.338 1604.217 1603.381 1603.381 1603.381 1603.381 1603.381 1603.381 1603.382 160</td> <td>2358.814 / / / / / / / / / / / / /</td> <td>64.417 42.875 41.822 42.875 41.822 42.825 42.825 42.825 42.825 42.825 42.825 42.825 42.825 40.723 39.873 39.972 40.729 40.729 43.595 47.797 44.965 39.728 42.57 42.57 42.57 42.57 42.57 42.57 42.57 44.88 42.57 44.076 44.0621 44.0621 44.065 40.05</td>	Cloudy Cl	23 1 2 3 4 5 6 7 8 9 100 211 223 3 14 15 16 17 223 3 4 5 6 7 8 90 211 223 3 4 5 6 7 8 90 112 233 4 5 6 7 8 9 100 211 12 33 14 15 16 17 18 9 </td <td>50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 96482.049 94621.424 104722.049 94621.424 104722.049 94621.424 10472.049 90889.988 113871.145 10470.471 72087.414 110889.820 10270.471 172087.414 110889.820 10247.94 96074.261 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 970974.977 97094.977</td> <td>1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.485 1554.801 1554.801 1554.801 1554.801 1558.4320 1558.4320 1558.4321 1558.4321 1558.4321 1558.4321 1558.2471 1558.25271 1538.250 1547.47 1558.25271 1538.250 1547.475 1558.4465 1558.25271 1538.250 1547.475 1558.431 1558.25271 1538.250 1547.475 1558.431 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271</td>	50733.42 A 81139.014 84247.965 110234.967 81274.197 117812.291 96482.049 994621.424 96482.049 94621.424 104722.049 94621.424 104722.049 94621.424 10472.049 90889.988 113871.145 10470.471 72087.414 110889.820 10270.471 172087.414 110889.820 10247.94 96074.261 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 97094.977 970974.977 97094.977	1235.26 Gaussian ω 1551.531 1553.306 1551.837 1551.485 1554.801 1554.801 1554.801 1554.801 1558.4320 1558.4320 1558.4321 1558.4321 1558.4321 1558.4321 1558.2471 1558.25271 1538.250 1547.47 1558.25271 1538.250 1547.475 1558.4465 1558.25271 1538.250 1547.475 1558.431 1558.25271 1538.250 1547.475 1558.431 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271 1558.25271	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705	1353.981 Lorentziar ω 1606.072 1605.348 1604.520 1603.452 1603.635 1603.635 1603.635 1603.635 1603.635 1603.636 1603.636 1603.637 1603.638 1603.638 1603.638 1603.638 1604.877 1605.386 1604.534 1604.534 1604.534 1604.534 1605.485 1605.485 1603.553 1604.501 1599.56 1605.455 1603.553 1605.455 1603.338 1604.217 1605.455 1603.338 1604.217 1603.381 1603.381 1603.381 1603.381 1603.381 1603.381 1603.382 160	2358.814 / / / / / / / / / / / / /	64.417 42.875 41.822 42.875 41.822 42.825 42.825 42.825 42.825 42.825 42.825 42.825 42.825 40.723 39.873 39.972 40.729 40.729 43.595 47.797 44.965 39.728 42.57 42.57 42.57 42.57 42.57 42.57 42.57 44.88 42.57 44.076 44.0621 44.0621 44.065 40.05
Facies Crinkly laminated chert Massive black chert Mas	Sample D1 C9E C9E C9E C	Cloudy Cl	23 1 2 3 4 5 6 7 8 9 10 11 122 23 14 15 16 7 8 920 21 22 23 4 5 6 7 8 9 11 122 23 3 4 5 6 7 8 9 10 122 23 4 5 6 7 8 9 11 22 12 13 14	50733.42 A 81139.014 84247.965 81274.197 117812.291 96482.040 99740.363 104722.049 94621.424 76401.849 76401.849 76401.849 104722.049 94621.424 10472.41 10472.448 1027.461 10470.471 10269.820 110270.471 10269.421 10470.471 10269.820 110270.421 10383.925 A 6 96074.214 31187.12 96074.261 163183.065 89369.269 110334.95 A 6 9612.14 31187.12 21098.50 27608.63 20427.94 39748.22 97204.997 10397.979 41352.992 4639.656 44166.430 56312.058 45188.85 73168.431 23480.728 67657.471 1088.820	1235.26 Gaussian 1551.531 1553.306 1551.437 1551.437 1551.437 1554.801 1554.801 1554.801 1558.474 1558.370 1541.28 1558.370 1541.28 1558.370 1541.386 1558.370 1541.386 1558.310 1551.196 1544.465 1538.629 1554.322 1550.28 Gaussian ω 1544.876 1535.24 1535.24 1550.28 Gaussian 1545.46 1545.46 1545.46 1545.46 1545.44 1545.46 1545.44 1545.46 1545.44 1545.46 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.44 1545.971 1547.718 1544.831	181.68 (D3) (D3) (D3) (D3) (D3) (D3) (D3) (D3)	210.14	227898.705 A 249454.102 231471.362 309154.216 214316.034 233613.843 233663.586 221909.302 245483.988 230445.622 245483.988 230445.622 245483.988 245046.786 225290.346 326564.198 245066.786 326564.198 277535.6267 272692.790 340452.029 327065.491 524237.465 223386.080 340452.029 327065.491 524237.465 223388.94 85978.57 97522.75 111436.05 75649.01 144272.61 388676.928 38232.394 93359.438 143880.758 154691.095 192282.549 145661.94 388753.272 191223.571 86118.975 15963.697	1353.981 Lorentziar 0 1606.072 1605.348 1604.520 1603.485 1603.485 1603.396 1602.708 1602.708 1602.708 1603.482 1603.482 1603.482 1603.482 1603.482 1604.537 1604.537 1604.537 1604.537 1604.538 1604.537 1604.538 1604.538 1604.538 1604.538 1605.458 1603.538 1605.458 1603.388 1605.485 1603.388 1604.848 1605.485 1603.388 1604.848 1605.485 1603.388 1604.856 1604.856 1604.963 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.485 1603.388 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.684 1605.685 1603.388 1605.684 1605.845 1603.388 1605.684 1605.845 1603.388 1605.684 1605.845 1603.388 1605.684 1605.845 1603.388 1605.684 1605.845 1603.388 1605.684 1605.845 1603.388 1605.845 1603.853 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.853 1605.845 1603.388 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1605.845 1	2358.814 (G) 3876.344 3733.886 4808.418 3496.225 4421.517 3984.699 3742.231 4005.609 3836.014 3915.663 3285.541 4097.431 3750.230 5220.696 4521.064 3818.621 8988.687 7257.978 4599.600 4599.600 1G) 1 3303.76 1124.688 14171.490 4599.600 125.797 2341.484 2980.033 2108.69 5659.766 1261.826 1265.797 2341.484 2980.033 2108.69 5659.766 2541.484 2980.033 2108.69 5659.766 2541.982 1461.283 4289.016 2441.982 1461.283 428.772 8898.087 2899.087 205.797 2341.484 2980.033 2108.69 2559.766 2541.982 21461.283 428.772 2898.087 2899.087 2899.087 2899.087 299.087 201.484	64.417 42.875 41.224 42.875 42.822 42.632 42.632 42.632 42.632 43.9581 39.581 39.581 39.581 39.581 39.733 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.973 40.723 39.728 40.729 40.729 40.729 40.729 40.723 39.728 40.729 40.72

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 | 1 | |
 | | Lorentziar | (D2) |
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| Facies

 | Sample | CM microtexture |
 | А | ω | 1 | Г
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 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 1
 | 46109.808 | 1627.318 | | 24.915
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 2
 | 57608.213
81163.559 | 1626.641 | 2151.683 | 25.441
24.699
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 4
 | 93574.661 | 1623.625 | 2067.600 | 29.801
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 5
 | 110950.990
101730.116 | 1622.727 | 2313.182
2290.850 | 31.646
29.225
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 7
 | 98738.463 | 1624.010 | 2188.244 | 29.710
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 8
 | 82641.228
118407.196 | 1624.282 | 1953.575
2571.134 | 27.794
30.341
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 10
 | 102360.795 | 1623.556 | 2216.096 | 30.437
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 11
 | 88126.586 | 1623.699 | 2007.864 | 28.870
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 12
 | 95363.448
83820.462 | 1623.872
1624.025 | | 28.428
29.207
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1
D1 | Bitumen-like | 14
 | 104491.436 | 1624.157 | 2559.427 | 26.792
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | DI | Bitumen-like
Bitumen-like | 15
 | 82490.853
63522.875 | 1626.255
1624.909 | 2016.079 | 26.861
27.301
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 17
 | 141881.175 | 1625.635 | 3690.129 | 25.190
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 18
 | 78972.189
71615.932 | 1626.361
1626.869 | 2069.010
1890.165 | 25.004
24.817
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 20
 | 109813.280 | 1625.800 | 2583.016 | 27.943
 | |
 | |
 | | |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 21
 | 77826.145
57721.293 | 1627.169 | 2131.118 | 23.895
23.325
 | |
 | |
 | | |
| Crinkly laminated chert

 | D1 | Bitumen-like | 23
 | 96221.77 | 1624.16 | 2215.88 | 28.57
 | |
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 | | Lorentziar | (D2) |
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 | |
 | | |
| Facies

 | Sample | CM microtexture |
 | Α | ω | 1 | Г
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 1
 | 46017.55 | 1626.46 | 1221.05 | 24.67
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 2
 | 22150.03
27970.44 | 1620.28
1623.54 | 434.98
598.16 | 33.65
30.82
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 4
 | 15035.78 | 1617.20 | 293.62 | 33.83
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 5
 | 15179.21
27292.66 | 1626.84
1626.92 | 414.40
698.27 | 23.97
25.63
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 6
7
 | 99472.825 | 1624.747 | 2398.142 | 27.240
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 8
 | 11850.523 | 1627.903 | 261.296 | 29.890
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 9
10
 | 37799.193
18429.284 | 1623.515
1625.407 | 830.879
510.800 | 29.951
23.588
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 11
 | 41155.769 | 1628.075 | 1024.930 | 26.355
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 12
13
 | 45012.994
28412.12 | 1626.634
1624.72 | 1280.696
713.94 | 22.974
26.97
 | |
 | |
 | | |
| Massive black chert

 | C9E | Bitumen-like | 14
 | 70858.421 | 1626.825 | 1769.482 | 26.276
 | |
 | |
 | | |
| Massive black chert

 | C9E | Interstitial | 15
 | 54157.279 | 1624.787 | 1364.438 | 26.020
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Interstitial
Interstitial | 16
 | 14929.826
60264.826 | 1627.033 | 413.200 | 23.637
29.902
 | |
 | |
 | | |
| Massive black chert

 | C9E | Cloudy | 18
 | 14915.711 | 1628.996 | 449.751 | 21.650
 | |
 | |
 | | |
| Massive black chert
Massive black chert

 | C9E
C9E | Cloudy
Cloudy | 19
20
 | 53089.834
141881.175 | 1627.620
1625.635 | 1832.329
3690.129 | 18.844
25.190
 | |
 | |
 | | |
| Massive black chert

 | C9E | Cloudy | 21
 | 53712.184 | 1627.643 | 1857.415 | 18.807
 | |
 | |
 | | |
| Massive black chert

 | C9E | Cloudy | 2.2
 | 15700 651 | | |
 | |
 | |
 | | |
|

 | | | 22
 | 15703.651 | 1626.691 | 532.811 | 19.175
 | |
 | |
 | | |
| Massive black chert

 | C9E | Cloudy | 22
 | 14123.983 | 1626.691 | 532.811
479.619 | 19.175
19.158
 | |
 | |
 | | |
|

 | | |
 | | | |
 | R ₂ (1) | ΔT C° (2)
 | ΔT C° (3 |) <mark>T C° (4</mark>
 | R _{D3} | R _{D4} |
| Massive black chert Facies Crinkly laminated chert

 | C9E
Sample
D1 | Cloudy
CM microtexture
Bitumen-like | 23
 | 14123.983
R ₁
1.68 | 1626.623 | 479.619
I _{D1} /(I _{D1} +I _G
0.6268 | 19.158
A _D /A _G
3.13
 | 0.7255 | 318.17
 | 304.85 | 366.07
 | 0.0947 | 0.0775 |
| Massive black chert Facies Crinkly laminated chert Crinkly laminated chert

 | C9E
Sample | Cloudy
CM microtexture
Bitumen-like
Bitumen-like | 23
 | 14123.983
R ₁
1.68
1.74 | 1626.623
Γ _{D1/G} | 479.619
I _{D1} /(I _{D1} +I _G
0.6268
0.6356 | 19.158
A _D /A _G
3.13
3.39
 | 0.7255
0.7306 |
 | 304.85
304.32 | 366.07
362.51
 | 0.0947 | 0.0775 |
| Massive black chert
Facies
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert

 | C9E
Sample
D1
D1
D1
D1 | Cloudy
CM microtexture
Bitumen-like
Bitumen-like
Bitumen-like
Bitumen-like | 23
1
2
3
4
 | 14123.983
R ₁
1.68
1.74
1.75
1.98 | 1626.623 | 479.619
I _{D1} /(I _{D1} +I _G
0.6268
0.6356
0.6363
0.6645 | 19.158
A _D /A _G
3.13
3.39
3.31
3.86
 | 0.7255
0.7306
0.7237
0.7290 | 318.17
315.90
318.97
316.61
 | 304.85
304.32
302.51
305.49 | 366.07
362.51
367.54
332.95
 | 0.0947
0.0997
0.0990
0.0955 | 0.0775
0.0762
0.0809
0.0740 |
| Massive black chert
Facies
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert

 | C9E
Sample
D1
D1
D1
D1
D1
D1 | Cloudy
CM microtexture
Bitumen-like
Bitumen-like
Bitumen-like
Bitumen-like
Bitumen-like | 23
1
2
3
4
5
 | 14123.983
R ₁
1.68
1.74
1.75
1.98
2.00 | 1626.623 | 479.619
I _{D1} /(I _{D1} +I _G
0.6268
0.6356
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| Massive black chert
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| Massive black chert
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| Massive black chert
Facies
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 | C9E Sample D1 | Cloudy
CM microtexture
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| Massive black chert
Facies
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| Massive black chert
Facies
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Crinkly laminated chert

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| Massive black chert
Facies
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| Massive black chert
Facies
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| Massive black chert
Facies
Crinkly laminated chert
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CM microtexture
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				1		Lorentzian	(D4)			Lorentzian	<i>(</i> D1)	
Fr	acies	Sample	CM microtexture		А	ω	/	Г	А	ω	(01)	Г
	d black chert	C2C C2C	Grain	1	110888.27	1195.16 1186.85	401.73 393.05	209.69	714507.90	1356.33 1356.33	8005.59	59.28
Laminate	d black chert d black chert	C2C	Grain Grain	3	133780.70 74280.81	1177.52	266.75	274.44 213.45	370808.96	1356.60	7138.29 4479.16	59.76 54.81
Laminate	d black chert d black chert	C2C C2C	Grain Grain	4	84303.25 141702.82	1187.84 1195.54	369.96 510.81	167.13 210.94	692698.96 903186.90	1356.74 1356.43	8013.66 9369.25	57.33 64.27
Laminate	d black chert d black chert	C2C C2C	Grain Grain	6	134078.29 148409.62	1191.95 1197.91	561.60 556.18	176.33 201.03	1025870.00 886707.92	1356.51 1356.13	10794.74 8806.43	63.31 67.27
	d black chert d black chert	C2C C2C	Grain Grain	8	101128.99 94040.30	1192.61 1196.41	409.04 412.04	183.75 167.03	723511.31 736152.37	1356.60 1356.41	7848.08 7918.25	61.33 61.87
	d black chert d black chert	C2C C2C	Grain Grain	10	91210.73 75658.61	1193.33 1196.05	430.02 303.90	153.54 185.08	781551.46 502913.07	1356.56 1356.75	8016.25 5286.02	65.03 63.39
Laminate	d black chert	C2C C2C	Grain Grain	12	113570.42 81221.90	1188.19	490.63 350.32	170.22	875042.19 615411.84	1356.42	9913.66 6693.75	58.60
Laminate	d black chert	C2C	Grain	14	85691.64	1200.56	327.54	196.12	569783.61	1356.55	6492.96	58.25
Laminate	d black chert d black chert	C2C C2C	Grain Grain	15 16	107487.74 55063.12	1203.91 1188.30	374.85 240.78	219.05 167.81	619027.89 376339.21	1357.15 1357.09	6963.57 4361.01	59.04 57.24
Laminate	d black chert d black chert	C2C C2C	Grain Grain	17	122290.35 63959.04	1202.73 1198.46	408.26 273.82	231.33 171.53	681324.07 462545.55	1357.00 1357.12	7698.50 5286.24	58.76 58.07
	d black chert d black chert	C2C C2C	Grain Grain	19	112394.81 51992.10	1190.23 1179.28	382.53 257.14	226.94 145.86	637699.27 350733.61	1357.48 1356.92	7399.50 3908.49	57.16 59.62
Laminate	d black chert d black chert	C2C C2C	Grain Grain	21	157322.40 127200.13	1197.44 1194.63	643.15 430.16	181.17 228.35	1074650.00 733657.60	1356.49 1356.95	11028.91 8193.53	64.99 59.49
Laminate	d black chert d black chert	C2C C2C	Bituminous-XcV Bituminous-XcV	23 24	93552.93 105770.04	1203.42 1203.83	370.23 410.28	187.97 192.50	520298.20 660841.26	1355.42 1355.10	4588.67 5817.20	76.26 76.41
	d black chert	C2C	Bituminous-XcV	25	102173.56	1203.21	414.18	182.68	591957.86	1355.23	4685.97	85.55
E	acies	Sample	CM microtexture		A	Lorentzian ω	(D4)	Г	А	Lorentzian ω	(D1)	Г
Granular cart	bonaceous chert	D4A	Mats-like network	1	146783.25	1199.64	530.22	210.31	921251.526	1356.435	10782.531	56.653
Granular cark	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	2	94290.10 156880.63	1193.20 1197.04	386.52 571.90	180.97 208.17	664291.674 997801.984	1356.706 1356.511	7643.005 11691.717	57.675 56.587
	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	4	108416.82 83519.13	1213.15 1198.88	408.14 358.46	199.18 171.13	688799.584 621021.756	1356.628 1356.852	8041.664 7140.186	56.802 57.717
	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	6	111076.88 106863.06	1200.32 1196.18	412.69 377.93	203.18 216.13	721823.561 631045.161	1356.973 1357.015	8637.836 7448.779	55.358 56.155
Granular cart	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	8	144162.04 126868.79	1195.22	531.29 474.91	205.55	914167.588 809623.385	1357.079	10851.579 9322.197	55.826
Granular cart	bonaceous chert	D4A	Mats-like network	10	187812.78	1207.98	621.71	233.61	1038100.000	1356.740	12140.436	56.701
Granular cart	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	11	123236.22 90632.40	1204.10 1202.02	401.39 333.03	238.75 205.81	743436.031 592336.070	1356.852 1357.180	8872.571 7081.274	55.514 55.416
Granular cart	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Mats-like network	13	109637.56 148483.17	1199.33 1207.82	378.78 456.68	222.20 256.43	672528.875 773798.586	1357.083 1357.150	7956.220 9522.561	56.024 53.768
	bonaceous chert bonaceous chert	D4A D4A	Mats-like network Grain	15	135801.09 99741.27	1201.65 1193.91	462.04 357.76	226.27 212.58	848006.545 591926.820	1357.141 1356.211	10074.487 6186.134	55.779 63.780
	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	17 18	132189.94 109305.09	1202.52 1199.09	452.93 442.35	224.23 183.42	727238.593 728837.847	1356.294 1355.930	7760.763 7655.861	62.398 63.440
Granular cart	bonaceous chert	D4A	Grain	19 20	113713.90	1191.69 1200.96	509.70	162.99	808783.656	1355.233	8044.657	67.181
Granular cark	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	21	106976.17 122802.80	1198.78	422.36 451.34	188.80 205.98	662559.132 712860.129	1355.671 1356.478	6024.937 7060.681	73.847 67.480
	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	22 23	111949.68 164055.09	1194.31 1198.60	396.17 607.97	216.10 203.93	685300.550 1027530.000	1356.408 1356.530	7286.141 10380.126	62.641 66.095
	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	24 25	188864.21 128147.05	1204.81 1194.82	609.07 483.11	241.70 199.99	1062840.000 836373.175	1356.996 1357.060	12314.596 9241.888	57.254 60.162
Granular cark	bonaceous chert	D4A	Grain	26	92727.16	1195.82	303.11	238.47	508730.144	1356.608	5553.282	60.935
Granular cark	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	27 28	184386.38 123427.00	1203.06 1202.14	633.11 524.02	223.60 173.17	1046230.000 950268.657	1356.631 1356.309	11551.635 9695.531	60.212 65.408
	bonaceous chert bonaceous chert	D4A D4A	Grain Grain	29 30	130148.59 141628.83	1198.61 1198.54	472.61 519.02	207.76 206.47	793165.725 862604.259	1356.291 1356.432	8307.966 9133.785	64.510 63.429
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<u> </u>	•				-	Gaussian	<u>` </u>	_		Lorentziar	<u>``</u>	_
	acies d black chert	Sample C2C	CM microtexture Grain	1	A 57424.90	ω	Î.	<u>Г</u> 126.81	A 222197.93	ω	1	Г 40.27
Laminate Laminate	d black chert d black chert	C2C C2C	Grain Grain	2	57424.90 47927.73	ω 1550.35 1547.03	/ 425.41 331.94	126.81 135.64	222197.93 213676.15	ω 1605.13 1605.58	/ 3663.99 3403.98	40.27
Laminate Laminate Laminate Laminate	d black chert d black chert d black chert d black chert d black chert	C2C C2C C2C C2C C2C	Grain Grain Grain Grain	2 3 4	57424.90 47927.73 34193.45 54900.97	ω 1550.35 1547.03 1555.40 1552.42	/ 425.41 331.94 214.89 427.78	126.81 135.64 149.49 120.57	222197.93 213676.15 111638.52 211734.95	W 1605.13 1605.58 1603.70 1604.82	/ 3663.99 3403.98 1813.47 3467.64	40.27 41.75 40.89 40.55
Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert d black chert d black chert d black chert d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain Grain	2 3 4 5 6	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1549.88	/ 425.41 331.94 214.89 427.78 571.64 668.74	126.81 135.64 149.49 120.57 118.72 115.54	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86	W 1605.13 1605.58 1603.70 1604.82 1603.91 1605.05	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08	40.27 41.75 40.89 40.55 41.83 40.14
Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert d black chert d black chert d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain	2 3 4 5 6 7 8	57424.90 47927.73 34193.45 54900.97 72239.56	ω 1550.35 1547.03 1555.40 1552.42 1545.23	/ 425.41 331.94 214.89 427.78 571.64 668.74 549.55 409.89	126.81 135.64 149.49 120.57 118.72	222197.93 213676.15 111638.52 211734.95 267262.16	ω 1605.13 1605.58 1603.70 1604.82 1603.91	/ 3663.99 3403.98 1813.47 3467.64 4248.44	40.27 41.75 40.89 40.55 41.83
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain Grain Grain Grain Grain	2 3 4 5 6 7 8 9	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02	<u>ω</u> 1550.35 1547.03 1555.40 1552.42 1545.23 1549.88 1542.05 1545.38 1545.59	/ 425.41 331.94 214.89 427.78 571.64 668.74 549.55 409.89 408.39	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.05 1604.99 1605.86 1604.25	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	2 3 4 5 6 7 8 9 10 11	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84	W 1550.35 1547.03 1555.40 1552.42 1545.23 1549.88 1542.05 1545.38 1545.38 1545.59 1551.69 1547.69	425.41 331.94 214.89 427.78 571.64 668.74 549.55 409.89 408.39 408.39 550.87 342.63	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 132.28 119.69	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1604.82 1605.86 1604.25 1606.31 1604.75	3663.99 3403.98 1813.47 3467.64 4248.44 4293.08 4296.20 3714.13 3384.91 3384.91 3881.34 2345.87	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	2 3 4 5 6 7 8 9 10 11 11 12 13	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 43654.84 61687.52 53728.40	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1549.88 1542.05 1545.38 1545.59 1551.69 1547.69 1547.69 1547.87 1548.88	425.41 331.94 214.89 427.78 571.64 668.74 549.55 409.89 408.39 550.87 342.63 472.36 411.19	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 132.28 119.69 122.69	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.05 1604.99 1605.86 1604.25 1606.31 1604.75 1605.10 1606.28	3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3384.91 3881.34 2345.87 4476.24 3460.45	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.27 41.17
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	22C 22C 22C 22C 22C 22C 22C 22C 22C 22C	Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	2 3 4 5 6 7 8 9 10 11 12 13 14 15	57424.90 47927.73 34193.45 54900.97 7239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 61667.52 53728.40 47517.31 52047.12	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1549.88 1542.05 1542.05 1545.38 1545.59 1551.69 1541.87 1548.88 1549.49 1548.28	425.41 331.94 214.89 427.78 571.64 668.74 408.39 408.39 550.87 342.63 472.36 411.19 357.39 359.57	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 135.54 119.69 122.69 122.75 124.91 135.98	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1605.05 1605.86 1604.25 1606.31 1605.66 1604.75 1605.10 1605.56 1605.56 1605.56	2 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3881.34 2345.87 3460.45 2845.53 3005.98	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.27 41.17 41.75 41.13
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	22C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	2 3 4 5 6 7 7 8 9 10 11 12 13 14	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 61687.52 53728.40 47517.31	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.28 1542.05 1545.38 1545.59 1551.69 1547.69 1541.87 1548.88 1549.49	425.41 331.94 214.89 427.78 571.64 668.74 668.74 549.55 409.89 408.39 408.39 408.39 408.39 402.36 40.36 50 40.36 400.36 400.36 400.36 4000	126.81 135.64 149.49 120.57 118.72 115.54 117.84 117.84 115.57 135.54 132.28 119.69 122.69 122.75 124.91	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52	ω 1605.13 1605.58 1603.70 1604.82 1603.05 1604.99 1605.86 1604.25 1606.31 1604.75 1605.10 1605.68 1605.56 1604.66 1605.78	3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3884.91 3881.34 2345.87 4476.24 3460.45 2845.53	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.27 41.17 41.75
Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate Laminate	d black chert d black chert	22C 22C 22C 22C 22C 22C 22C 22C 22C 22C	Grain Grain	2 3 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 18	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 33229.92	ω 1550.35 1547.03 1555.40 1555.41 1545.23 1545.23 1545.23 1545.38 1545.38 1547.69 1547.69 1547.69 1547.69 1548.88 1548.88 1548.28 1550.83 1545.11	/ 425.41 331.94 214.89 427.78 571.64 668.74 599.55 409.89 408.39 550.87 342.63 472.36 411.19 357.39 216.29 410.82 282.80	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.54 135.54 132.26 122.69 122.69 122.75 124.91 135.98 123.27 121.29 127.00	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.56 1604.92 1605.86 1605.10 1605.10 1605.26 1605.37 1605.37 1605.37 1605.37	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3384.91 3384.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 1810.25 3474.12 2364.22	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 41.17 41.75 41.13 41.98 42.28 43.72
Laminate Laminate	d black chert d black chert	22C 22C 22C 22C 22C 22C 22C 22C 22C 22C	Grain Grain	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77558.48 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15	ω 1550.35 1547.03 1555.40 1555.41 1545.23 1545.23 1542.05 1545.38 1545.39 1545.38 1545.38 1547.69 1541.87 1548.88 1545.187 1548.28 1550.83 1545.11 1542.03 1543.91 1542.03 1543.91	425.41 331.94 214.89 427.78 571.64 409.89 406.39 550.87 342.63 472.36 411.19 357.39 350.87 216.29 410.82 282.80 343.72 228.83	126.81 135.64 149.49 120.57 118.72 115.54 115.54 115.57 135.54 132.28 119.69 122.69 122.69 122.69 122.75 124.91 135.98 123.27 121.29 127.00 121.35	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1604.82 1605.05 1604.82 1605.05 1604.82 1605.05 1604.25 1605.31 1605.26 1605.56 1605.77 1605.37 1605.37 1605.46 1605.77 1605.64 1605.17 1605.49	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 1810.25 3474.12 2364.22 3256.35 1650.90	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.78 42.27 41.17 41.75 41.73 41.98 42.28 43.72 43.72 42.71 41.73 41.98 43.72
Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 61667.52 53728.40 47517.31 52047.12 28381.21 53047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67	ω 1550.35 1547.03 1555.40 1555.41 1547.03 1552.42 1545.23 1545.23 1545.26 1545.27 1545.28 1542.05 1545.38 1545.48 1548.28 1548.28 1548.28 1548.28 1548.28 1545.31 1543.31	1 425.41 331.94 427.78 571.64 409.89 408.39 550.87 342.63 411.19 357.36 411.19 355.37 216.29 410.82 282.80 343.72 228.83 708.44 424.97	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.54 135.54 135.54 132.28 122.69 122.69 122.75 122.75 124.91 135.98 123.77 121.29 127.00 123.78 138.58 120.57	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1605.05 1604.25 1605.16 1604.25 1605.05 1606.28 1605.56 1605.56 1605.61 1605.77 1605.78 1605.64 1605.71 1605.64 1605.71 1605.64 1605.64 1605.77 1605.64 1605.64 1605.77 1605.64 1605.71 1605.64 1605.64 1605.65 1605.66 1605.17 1606.27 1606.27 1606.28	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3884.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 18110.25 2845.53 3005.98 18110.25 2845.53 3005.98 18110.25 2847.21 23256.35 1650.90 33773.31	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.75 42.27 41.17 41.75 41.13 41.98 41.98 42.27 41.17 41.75 41.13 41.98 42.28 43.72 42.28 43.72 42.63
Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain	2 3 4 5 6 7 8 9 9 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 58923.02 5823.02 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.26 1545.27 1545.28 1545.29 1545.38 1545.38 1545.38 1545.38 1545.38 1545.38 1545.38 1545.38 1545.38 1545.31 1545.31 1545.31 1545.31 1545.31 1545.30 1545.30 1545.31 1545.30 1545.30 1545.36 1545.30 1545.30 1545.30 1545.30 1544.40	1 425.41 331.94 427.78 571.64 668.74 549.55 409.89 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 352.63 411.19 352.39 359.57 216.29 410.82 228.83 353.57 216.29 410.82 228.83 7708.44 40.88 554.18	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 117.84 115.57 135.54 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.91 121.35 123.78 135.98 123.78 135.98 123.78 135.98 123.78 135.98 123.78 135.98 123.78 123.78 120.52 126.91 145.52	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1605.05 1604.82 1605.05 1604.82 1605.05 1604.25 1606.28 1605.56 1605.64 1605.78 1605.61 1605.64 1605.78 1605.17 1605.64 1605.17 1606.21 1606.11 1606.11 1605.26	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3884.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 1810.25 3474.12 23664.22 23664.22 23664.22 3256.35 1650.90 5373.31 3713.64 2698.08 3804.51	$\begin{array}{c} 40.27\\ 41.75\\ 40.89\\ 40.89\\ 40.55\\ 41.83\\ 40.14\\ 43.35\\ 42.62\\ 43.04\\ 40.68\\ 40.75\\ 41.17\\ 41.75\\ 41.17\\ 41.78\\ 41.98\\ 42.27\\ 43.372\\ 43.372\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.55\\ 42.54\\ 42.54\\ 42.55\\ 42.54\\ $
Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain	2 3 4 5 6 7 8 9 10 11 11 12 13 14 15 16 16 17 18 19 20 21 22 23	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68335.51 50426.60 58923.02 77568.48 43654.84 43654.84 43654.84 43654.84 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 54520.37	ω 1550.35 1547.03 1555.40 1555.41 1545.23 1545.23 1545.38 1545.38 1545.38 1545.38 1545.38 1545.38 1547.69 1547.69 1547.69 1548.28 1550.83 1545.11 1542.03 1545.31 1545.31 1542.03 1545.31 1545.36 1545.36 1547.69 1547.69 1548.28 1550.83 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.30	1 425.41 331.94 214.89 427.78 571.64 403.89 408.39 550.87 342.63 472.36 355.72 216.29 411.19 355.37 216.29 410.82 228.83 708.44 424.97 440.98 554.18	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 115.57 132.28 119.69 122.75 124.91 122.75 124.91 123.78 123.27 121.29 123.78 123.85 123.78 123.85 123.78 123.54 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.75 123.78 125.78 12	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61	ω 1605.13 1605.58 1603.70 1604.82 1605.58 1603.70 1605.86 1605.86 1605.11 1605.25 1605.31 1605.10 1605.56 1605.76 1605.76 1605.76 1605.77 1605.64 1605.77 1605.64 1605.77 1606.27 1606.19 1606.11	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3384.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 18110.25 2474.12 2356.35 1650.90 53773.31 5474.12 2356.35 1650.90 53773.31 3711.64 2698.08 3804.51 3311.68	$\begin{array}{c} 40.27\\ 41.75\\ 40.89\\ 40.55\\ 41.83\\ 40.14\\ 43.35\\ 42.62\\ 43.04\\ 40.75\\ 42.62\\ 43.04\\ 40.75\\ 42.27\\ 41.17\\ 41.75\\ 41.198\\ 41.98\\ 42.28\\ 43.72\\ 43.33\\ 42.63\\ 42.59\\ \end{array}$
Laminate Laminate	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain	2 3 4 5 6 7 8 9 9 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 58923.02 5823.02 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91	ω 1550.35 1547.03 1555.40 1555.41 1545.23 1542.05 1542.05 1545.38 1542.05 1545.38 1542.05 1545.38 1545.38 1545.47.69 1547.69 1548.28 1548.28 1542.03 1545.38 1545.11 1542.03 1545.30 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36	1 425.41 331.94 214.89 427.78 571.64 403.89 408.39 550.87 342.63 472.36 355.72 216.29 411.19 355.37 216.29 410.82 228.83 708.44 424.97 440.98 554.18	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 117.84 115.57 135.54 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.91 121.35 123.78 135.98 123.78 135.98 123.78 135.98 123.78 135.98 123.78 135.98 123.78 123.78 120.52 126.91 145.52	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1605.05 1605.05 1605.05 1605.05 1604.82 1605.05 1606.28 1605.56 1605.56 1605.64 1605.77 1605.61 1605.37 1605.64 1605.77 1605.61 1606.27 1606.17 1606.19 1605.26 1607.55	/ 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 3384.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 18110.25 2474.12 2356.35 1650.90 53773.31 5474.12 2356.35 1650.90 53773.31 3711.64 2698.08 3804.51 3311.68	$\begin{array}{c} 40.27\\ 41.75\\ 40.89\\ 40.89\\ 40.55\\ 41.83\\ 40.14\\ 43.35\\ 42.62\\ 43.04\\ 40.68\\ 40.75\\ 41.17\\ 41.75\\ 41.17\\ 41.78\\ 41.98\\ 42.27\\ 43.372\\ 43.372\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 43.43\\ 42.63\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.54\\ 42.55\\ 42.54\\ 42.54\\ 42.55\\ 42.54\\ $
Laminate Lam	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain	2 3 4 5 6 7 7 8 9 9 10 11 11 12 13 14 15 16 17 7 18 19 20 21 22 23 24 25 2 2 1	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 58605.44 71043.012	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.26 1545.27 1545.28 1545.29 1545.38 1545.38 1545.42 1545.48 1545.48 1549.49 1548.28 1550.83 1545.36 1543.41 1551.07 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.38 0 0	/ 425.41 331.94 427.78 571.64 427.78 571.64 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 408.89 472.36 472	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 117.84 115.57 135.54 117.84 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.91 135.98 123.27 124.91 127.00 121.35 123.78 138.58 120.52 124.92 120.52 124.92 125.52 124.42	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 214304.64 214304.64 178619.52 186046.93 114231.68 114231.68 114231.68 120762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 25827.95 230293.18 A 268342.883	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1604.99 1605.86 1604.25 1605.05 1604.25 1605.06 1605.78 1605.78 1605.71 1605.64 1605.78 1605.78 1605.11 1605.64 1605.78 1605.61 1606.17 1606.19 1607.55 Lorentziar ω 1604.438	/ 3663.99 3403.98 1813.47 3467.64 4298.620 3714.13 3884.91 3881.34 2345.87 44766.24 3460.45 2845.53 3005.98 1810.25 3474.12 23664.22 23256.35 1650.90 5373.31 3713.64 2698.08 3804.51 3311.68 / 4350.440	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 42.62 43.04 40.68 40.75 41.17 41.75 41.17 41.75 41.13 41.98 42.27 41.13 41.98 42.21 43.33 42.63 42.21 37.42 43.33 42.63 42.63 42.50 42.50 42.50 42.50 42.51 45.52 55.52 55.555
Laminate Lam	d black chert d blac	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grab Grain G	2 3 4 5 6 6 7 7 8 9 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 23 24 25 10 11 12 20 21 21 23 24 25 23 24 25 23 24 25 23 24 25 25 25 25 25 25 25 25 25 25	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 58605.44 71043.012 46132.207 46132.207 46844.071	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.23 1545.23 1545.59 1545.59 1545.59 1545.69 1547.69 1544.28 150.083 1545.11 1542.03 1543.91 1543.91 1545.36 1545.36 1545.30 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1551.989 1542.000 1546.813	/ 425.41 331.94 427.78 571.64 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 350.37 322.63 411.19 357.39 359.57 216.29 40.82 410.82 51.83 51.8	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 115.57 135.54 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.91 135.98 123.27 121.29 127.00 121.35 123.78 138.58 120.52 124.92 124.92 125.52 124.92 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 125.52 124.92 127.55 127.52 12	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 214304.64 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 A 268342.883 243934.215 313333.545	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.86 1604.82 1605.86 1604.82 1605.86 1604.75 1605.86 1604.75 1605.78 1605.66 1605.77 1605.61 1605.77 1605.77 1605.61 1605.77 1606.11 1605.26 1607.55 Lorentziar ω 1604.433 1605.439	/ 3663.99 3403.98 1813.47 3467.64 4298.44 4993.08 4296.20 3714.13 3881.34 2345.87 4476.24 3881.34 2345.87 4476.24 3460.45 3384.91 3881.34 2345.87 3005.98 1810.25 3474.12 23664.22 3474.12 23664.22 3474.12 23664.22 3474.12 23664.23 3474.12 23664.23 3474.12 23664.24 3476.31 3713.64 2698.08 3804.51 3311.68 1 () 4350.440 3662.824 4927.163	40.27 41.75 40.89 40.55 41.83 40.14 43.35 40.14 43.35 40.14 43.35 42.62 43.04 40.68 40.75 41.075 41.075 41.075 41.075 41.075 41.03 742 42.01 41.08 42.27 41.03 742 42.01 41.03 42.62 42.01 41.03 41.03 42.62 41.03 42.02 42.01 41.03 42.02 42.01 41.03 42.02 42.01 41.03 42.02 42.01 41.03 42.02 42.01 41.03 42.02 42.01 41.03 42.02 42.01 42.02 42.01 42.02 42.01 42.02 43.03 42.64 43.02 45.62 44.00 45.42 45.444 45.4444 45.44444445 45.44444445 45
Laminate Caminate Laminate Laminate Caminate Laminate Caminate Cam	d black chert d blac	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Crain Grab Grain G	2 3 4 5 6 6 7 7 8 9 9 10 11 12 13 14 15 16 16 16 16 16 12 22 23 24 25 24 25 1 24 25 3 4 4 5 5 6 6 6 6 6 6 6 6 6 6 6 6 6	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68335.51 50426.02 58923.02 77568.48 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 54560.58 5400.5800.5800.5800.58000.580	ω 1550.35 1547.03 1555.40 1552.42 1547.03 1552.42 1545.23 1545.23 1545.23 1545.23 1545.59 1545.59 1547.69 1541.87 1548.28 1549.23 1543.48 1544.20 1543.203 1543.91 1543.91 1545.36 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1542.000 1546.813 1543.641	/ 425.41 331.94 427.78 571.64 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 350.87 322.63 411.19 350.87 350.87 322.63 411.19 359.57 216.28 357.39 410.82 410.82 42.97 440.98 343.72 228.83 770.844 42.97 440.98 343.72 228.83 770.844 42.97 440.97 440.97 440.97 440.97 440.97 440.97 440.83 554.18 425.50 554.645 564.645 408.780 357.016	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 132.28 132.26 122.75 124.91 122.75 124.91 123.54 123.27 121.29 123.27 121.29 123.28 123.58 123.52 124.42 Г 116.610 121.391 110.624 124.42 Г	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 A 268342.883 243934.215 313333.545 223180.211 206149.985	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.95 1604.82 1605.96 1604.82 1604.82 1604.99 1604.75 1605.86 1604.75 1605.78 1605.61 1605.64 1605.77 1605.64 1605.77 1605.64 1605.64 1605.71 1606.19 1606.11 1605.26 1607.55 Lorentziar ω 1604.4613 1604.613 1604.613 1604.613 1604.643 1604.643 1604.643 1604.643 1604.643 1604.643 1604.643 1604.643 1605.058	/ 3663.99 3403.98 1813.47 3467.64 4298.04 4298.04 4298.04 3714.13 3881.34 2345.87 4296.20 3714.13 3881.34 2345.87 4476.24 4477.16 3389.462 3127.368	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.26 43.04 40.75 42.27 43.04 40.68 40.75 42.27 41.17 41.17 41.73 41.13 41.98 43.72 43.33 42.69 45.42 46.50 45.42 46.50 45.42 46.50
Laminate Caminate Laminate Laminate Laminate Laminate Laminate Caminate Laminate Caminate Laminate Caminate Laminate Caminate Laminate Lam	d black chert d blac	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grab Grain G	2 3 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 17 18 19 20 22 23 24 25 24 25 1 24 5 6 6 7 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77558.48 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 54520.37 54520.37 54520.37 55520.37 542520.37 5425200.37 5425200.3	ω 1550.35 1547.03 1555.40 1555.41 1545.23 1545.23 1545.38 1542.05 1545.38 1545.38 1545.38 1547.69 1541.87 1548.88 1545.36 1545.36 1545.36 1542.03 1543.91 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1542.03 1542.03 1543.970 1542.03 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.36 1545.37 1543.3703 1543.641	/ 425.41 331.94 214.89 427.78 571.64 409.89 408.39 550.87 342.63 472.36 472.36 472.36 472.36 472.36 1411.19 359.57 216.29 410.82 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 343.72 282.80 344.45 544.18 442.50 (D3) 7 584.645 546.645 348.	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 119.69 122.69 122.69 122.75 124.91 135.98 123.27 124.91 123.78 123.28 123.27 121.29 127.00 121.35 126.91 124.42 F 110.624 124.298 F 124.42 F 110.624 124.298 126.912 124.299 125.907 119.403	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 A 268342.883 243934.215 313333.545 23180.211 206149.985 217591.742 212789.168	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1604.99 1605.05 1604.99 1605.05 1604.25 1605.31 1605.36 1605.37 1605.46 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1605.61 1606.19 1606.11 1605.26 1607.75 Lorentziar ω 1604.438 1605.439 1604.646 1605.031 1604.63 1605.035	/ 3663.99 3403.98 1813.47 3467.64 4298.20 3714.13 3384.91 3384.91 3384.91 3384.91 3384.91 3445.87 4476.24 3460.45 2845.53 3005.98 1810.25 3474.12 2364.22 3256.35 1650.90 5373.31 3713.64 2698.08 3804.51 3311.68 / 4350.440 3662.824 4927.163 3389.462 3389.462 3312.7368 3491.812 3316.4066	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 42.62 43.04 40.68 40.75 42.27 41.17 41.17 41.75 41.17 41.75 41.17 41.13 41.98 42.24 43.32 42.59 45.42 45.444 45.4445 45.4445 45.4445 45.4445 45.
Laminate Caminate Laminate Laminate Laminate Laminate Laminate Laminate Caminate Cam	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grab Grain G	2 3 4 5 6 6 7 7 8 9 9 10 11 12 13 14 15 16 6 7 17 18 19 20 21 22 23 24 25 5 6 6 17 17 18 19 19 10 11 12 15 15 16 16 17 17 17 18 19 10 10 11 11 15 15 16 16 17 17 17 18 19 19 10 11 11 15 17 17 17 18 19 19 10 11 11 15 17 17 17 17 17 17 17 17 17 17	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 58923.02 577568.48 43654.84 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 58605.44 71043.012 46132.207 68845.071 54608.6312 50266.088 54479.823 42985.521 65626.6905	ω 1550.35 1547.03 1555.40 1552.42 1547.03 1547.03 1552.42 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.38 1545.39 1547.69 1541.87 1548.88 1550.83 1545.36 1543.91 1543.91 1553.44 1551.07 1543.61 1545.36 1545.36 1545.36 1545.36 1545.36 1543.361 1543.93 1543.9703 1543.9703 1543.641 1548.926 1543.143 1546.758	/ 425.41 331.94 427.78 571.64 427.78 571.64 408.87 408.89 408.87 408.89 408.89 408.87 408.89 408.87 408.89 408.87 409.89 357.37 216.29 410.82 282.80 377.37 40.88 377.84 424.97 40.88 554.18 425.50 155.55 406.49 406.494 338.202 518.453 358.402 358.402 357.39 357.315 358.4645 377.015 358.4645 377.015 358.4645 377.015 358.4645 377.015 358.4645 406.494 338.202 318.453 318.453 318.453 318.453 317.015 358.4645 337.015 358.4645 337.015 358.4645 337.015 358.4645 337.015 358.4645 338.202 318.453 358.455 358.455 358.455 358.455 357.015 358.4645 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 357.015 358.4645 358.4655 358.4	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 117.84 115.57 135.54 117.84 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.54 123.59 122.59 122.59 127.00 121.35 123.78 138.58 120.52 124.92 127.50 121.39 127.00 121.39 127.00 121.35 123.78 138.58 120.52 124.92 124.92 124.92 124.92 124.92 125.907 118.910 125.907	222197.93 213676.15 111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 25827.95 230293.18 A 268342.883 243934.215 233133.545 223180.211 206149.985 217591.742 212789.168	ω 1605.13 1605.58 1603.70 1604.82 1605.03 1605.05 1604.82 1605.05 1604.25 1605.06 1604.25 1605.10 1605.66 1605.78 1605.78 1605.61 1605.78 1605.61 1605.78 1605.17 1606.19 1606.11 1605.26 1607.55 Lorentzian 0 1604.433 1605.439 1604.613 1604.633 1605.37 1604.633 1604.633 1605.39 1604.643 1605.035 1605.035 1605.035 1605.035 1605.035 1605.035 1605.035	/ 3663.99 3403.98 1813.47 3467.64 4298.44 4993.08 4228.44 4993.08 3714.13 3884.91 3881.34 2345.87 4476.24 3460.45 2845.53 3005.98 1810.25 3474.12 2364.22 3256.35 1650.90 5373.31 3713.64 2698.08 380.451 3311.68 / 4350.440 3662.824 4927.163 3389.462 3127.368 3491.812 3316.406 127.368 3491.812 3316.406 3491.812 3316.405 3476.412 3476.412 3476.412 3476.412 3476.412 3476.412 3476.422 3477.422 3476.422 34777.4	40.27 41.75 40.89 40.55 41.83 40.14 43.35 40.14 43.35 42.62 43.04 40.75 41.17 41.75 41.77 41.77 41.77 41.73 41.98 42.27 41.13 41.98 42.27 42.17 41.13 41.98 42.23 42.01 37.42 42.01 42.63 42.73 43.73 44.744 44.744 44.7
Laminate Caminate Laminate Laminate Laminate Laminate Laminate Caminate Laminate Laminate Caminate Cam	d black chert d black chert bonaceous chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Gra Grain Gr	2 3 4 5 6 7 7 7 10 11 12 13 14 15 16 10 11 12 13 14 15 16 16 20 22 23 24 25 5 6 7 7 8 9 9 10 0 11 12 21 22 23 24 25 5 6 6 7 7 8 9 9 10 11 12 14 14 15 16 16 17 17 18 18 19 19 20 20 22 23 24 25 5 6 6 7 7 7 8 8 9 9 11 12 21 22 23 24 25 5 6 6 7 7 7 8 8 9 9 11 12 21 22 25 25 25 25 25 25 25 25 25	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77568.48 43654.84 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 58605.44 71043.012 46132.207 46132.207 46844.5071 54086.312 50266.088 54479.823 42985.521 50266.088 54479.823 42985.521 50266.088	ω 1550.35 1547.03 1557.40 1552.42 1547.03 1547.03 1552.42 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.38 1545.59 1547.69 1548.28 150.03 1548.28 1550.83 1545.31 1542.03 1543.91 1543.91 1543.91 1543.361 1543.361 1544.29 0 1551.989 1542.000 1546.813 1539.703 1543.343 1543.641 1548.926 1543.143 1546.758 1543.299	/ 425.41 331.94 427.78 571.64 427.78 571.64 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 350.87 342.63 472.36 572.339 372.08 37	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 115.57 135.54 117.84 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.91 135.98 123.27 124.91 121.39 127.00 121.35 123.78 138.58 120.52 124.92 125.907 119.403 118.916 135.52 124.91 125.907 119.403 118.916	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 A 268342.883 243934.215 230293.18 A 268342.883 243934.215 233180.211 206149.985 217591.742 223180.211 206149.985 217591.742 217591.742 226844.821 220806.954	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1604.82 1605.86 1604.82 1605.86 1604.75 1605.86 1604.75 1605.86 1604.75 1605.78 1605.61 1605.778 1605.71 1605.64 1605.77 1606.11 1605.26 1607.55 Lorentziar ω 1604.433 1605.439 1604.613 1605.438 1605.335 1604.613 1604.613 1605.035 1605.035 1605.035 1605.035 1605.628 1605.628 1605.628 1605.628 1605.628 1605.628 1605.628 1605.628 1604.239 <td>/ 3663.99 3403.98 1813.47 3467.64 4298.02 3714.13 3881.34 2345.87 3384.91 3881.34 2345.87 366.42 3474.12 23664.22 3474.12 23664.22 3474.12 23664.22 3474.12 23664.22 3474.12 23664.23 3713.64 2698.08 380.451 3311.68 / 4350.440 3662.824 4927.163 3389.462 3127.368 3491.812 312.368 3491.812 312.5366 3470.5399 4256.367 3005.98 3405.98</td> <td>40.27 41.75 40.89 40.55 41.83 40.14 43.35 40.14 43.35 40.64 43.04 40.68 40.75 41.07 41.75 41.73 41.98 42.27 41.17 41.98 42.27 41.17 41.98 42.27 41.17 41.98 42.24 43.33 42.63 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 43.73 42.73 43.74 43.73 42.73 43.74 43.75</td>	/ 3663.99 3403.98 1813.47 3467.64 4298.02 3714.13 3881.34 2345.87 3384.91 3881.34 2345.87 366.42 3474.12 23664.22 3474.12 23664.22 3474.12 23664.22 3474.12 23664.22 3474.12 23664.23 3713.64 2698.08 380.451 3311.68 / 4350.440 3662.824 4927.163 3389.462 3127.368 3491.812 312.368 3491.812 312.5366 3470.5399 4256.367 3005.98 3405.98	40.27 41.75 40.89 40.55 41.83 40.14 43.35 40.14 43.35 40.64 43.04 40.68 40.75 41.07 41.75 41.73 41.98 42.27 41.17 41.98 42.27 41.17 41.98 42.27 41.17 41.98 42.24 43.33 42.63 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 42.73 43.96 43.73 43.73 42.73 43.74 43.73 42.73 43.74 43.75
Laminate Caminate Laminate Laminate Caminate Cam	d black chert d black chert	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Crain Grain Crain	2 3 4 4 5 6 7 7 8 9 9 10 11 12 13 14 15 16 17 7 8 9 20 21 22 23 24 25 6 6 7 7 8 9 9 10 11 12 21 22 23 24 25 6 6 7 7 8 9 9 10 11 12 21 22 23 24 25 6 6 7 7 8 9 9 10 11 12 21 22 23 24 25 6 6 7 7 8 8 9 10 11 12 21 22 23 24 25 6 6 7 7 8 8 9 10 11 12 21 22 23 24 25 7 7 8 8 9 10 11 11 12 21 22 3 24 25 8 9 10 10 10 10 10 10 10 10 10 10	57424.90 47927.73 34193.45 54900.97 72239.56 82246.60 68935.51 50426.02 58923.02 77558.48 43654.84 61687.52 53728.40 47517.31 52047.12 28381.21 53041.85 38229.92 44401.31 30151.15 104506.67 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 59572.03 85844.91 54520.37 54520.37 54520.37 54520.37 54520.37 54520.37 54520.37 54285.521 54286.52 54285.521 54286.312 54486.312 54486.312 54286.312 54486.312 5	ω 1550.35 1547.03 1557.40 1552.42 1547.03 1552.42 1547.03 1545.23 1545.23 1545.23 1545.59 1545.59 1547.69 1541.87 1548.28 1543.391 1543.91 1543.91 1545.36 1545.36 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1545.30 1546.2000 1546.230 1543.30.703 1543.641 1543.641 1548.926 1543.467 1549.2627	/ 425.41 331.94 427.78 571.64 427.78 571.64 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 408.39 350.87 322.63 472.36 472.36 472.36 472.36 472.36 359.57 282.80 357.95 282.80 357.95 282.80 357.35 283.83 778.44 424.97 440.92 440.82 541.85 554.18 422.50 (D3) 554.64 554.18 422.50 (D3) 554.64 554.18 422.50 (D3) 554.64 554.18 422.50 (D3) 554.64 554.18 422.50 (D3) 554.64 554.18 422.50 (D3) 554.64 554.18 425.50 (D3) 554.64 554.18 408.780 357.015 564.645	126.81 135.64 149.49 120.57 118.72 115.54 117.84 115.57 135.54 115.57 132.28 119.69 122.69 122.75 124.91 135.98 123.27 124.29 123.28 123.28 123.28 123.27 121.23 123.28 123.28 123.28 124.29 124.29 124.29 124.29 124.29 124.29 124.29 124.29 124.29 124.29 124.29 125.907 118.53 126.912 125.907 118.532 126.912 125.907 118.532 126.912 125.907 118.532 125.907 127.90 127.9	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 A 268342.883 243934.215 313333.545 23380.211 206149.985 217591.742 212789.168 243934.215 31333.545 217591.742 212789.168 243934.215 314876.463 243934.215 314876.463 243934.215	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.86 1604.82 1603.70 1604.82 1604.82 1604.82 1604.75 1605.86 1604.75 1605.78 1605.61 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1606.19 1606.27 1606.11 1605.26 1607.55 Lorentziar ω 1604.643 1605.058 1605.058 1605.058 1605.0258 1605.628 1605.628 1605.280 1604.641 1605.2295	/ 3663.99 3403.98 1813.47 3467.64 4228.44 4993.08 4226.20 3714.13 3881.34 2345.87 4276.24 3460.45 2845.53 3005.98 1810.25 3474.12 2364.22 2364.22 23256.35 1650.90 5377.31 3713.64 2698.08 3804.51 3311.68 6 1 4350.440 3662.824 4927.163 3389.462 127.368 3491.812 3389.462 127.368 3491.812 3389.462 5025.870 3848.785 5025.870 3848.785 5025.870 3848.785 3107.317	40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.27 41.07 41.17 41.75 41.17 41.75 41.17 41.75 42.28 43.33 42.28 43.33 42.28 43.33 42.59 45.42 45.445 45.445 45.445 45.445 45.445 45.445 45.445 45.445 45.445 45.445 45.455 45.445 45.445 45.445 45.4
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243934.215 231333.545 231333.545 223180.211 270806.954 212789.168 2268342.883 243934.215 231345.443 206327.874 212789.168 226484.821 212789.1742 212789.168 226484.821 212789.1742 212789.168 226484.821 212789.168 236484.821 212789.168 236484.821 212789.1742 212789.168 236484.821 212789.168 236484.821 212789.1742 212789.1742 212789.1742 212789.1742 212789.1742 212789.1742 21379.1742 21379.1742 21379.1742 2256845.008 215552.674 314875.459 23288.777 31299.774 31873.509 280888.328</td> <td>ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.85 1605.86 1604.82 1605.86 1604.75 1604.75 1604.75 1605.86 1604.75 1605.78 1605.77 1605.66 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1606.19 1606.11 1605.26 1604.63 1604.643 1605.35 1605.058 1604.643 1605.058 1605.058 1605.2295 1604.643 1605.235 1604.231 1604.231 1604.243 1605.035 1604.243 1605.295</td> <td>/ 3663.99 3403.98 1813.47 3467.64 4298.44 4993.08 4228.44 4993.08 3714.13 3881.34 2345.87 3384.91 3384.91 3384.91 3384.91 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211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 284379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 258827.95 230293.18 243934.215 231333.545 231333.545 223180.211 270806.954 212789.168 2268342.883 243934.215 231345.443 206327.874 212789.168 226484.821 212789.1742 212789.168 226484.821 212789.1742 212789.168 226484.821 212789.168 236484.821 212789.168 236484.821 212789.1742 212789.168 236484.821 212789.168 236484.821 212789.1742 212789.1742 212789.1742 212789.1742 212789.1742 212789.1742 21379.1742 21379.1742 21379.1742 2256845.008 215552.674 314875.459 23288.777 31299.774 31873.509 280888.328	ω 1605.13 1605.58 1603.70 1604.82 1603.91 1605.85 1605.86 1604.82 1605.86 1604.75 1604.75 1604.75 1605.86 1604.75 1605.78 1605.77 1605.66 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1605.64 1605.77 1606.19 1606.11 1605.26 1604.63 1604.643 1605.35 1605.058 1604.643 1605.058 1605.058 1605.2295 1604.643 1605.235 1604.231 1604.231 1604.243 1605.035 1604.243 1605.295	/ 3663.99 3403.98 1813.47 3467.64 4298.44 4993.08 4228.44 4993.08 3714.13 3881.34 2345.87 3384.91 3384.91 3384.91 3384.91 3384.91 3474.12 3664.22 3474.12	40.27 41.75 40.84 40.89 40.55 40.85 40.55 41.83 40.14 43.35 42.62 43.04 40.75 42.27 41.17 41.17 41.75 41.17 41.17 41.17 41.13 41.98 42.28 43.72 42.01 37.42 43.33 42.59 45.42 44.41 42.83 42.59 45.42 44.59 45.42 44.59 45.42 44.59 45.42 44.59 45.42 44.59 45.42 44.59 45.42 44.59 45.42 45.59 45.42 46.50 41.43 39.62 41.43 39.62 41.43 41.675 42.59 45.42 46.50 41.43 41.675 42.59 45.42 45.42 45.59 45.42 45.4
Laminate Tranular cart Granular Granular Granular Granular Granular Granular Granular Granu	d black chert d blac	C2C C2C C2C C2C C2C C2C C2C C2C C2C C2C	Grain Mats-like network Mats-like network	2 2 3 3 4 4 5 6 6 7 7 8 9 9 10 11 12 20 21 22 23 24 25 1 1 12 2 3 4 5 6 6 7 7 8 9 9 10 11 12 20 22 23 24 25 5 6 6 7 7 8 9 9 10 11 13 13 14 15 16 7 7 7 8 9 9 10 11 11 13 13 14 15 16 6 7 7 7 8 18 19 19 20 21 22 23 24 25 25 10 11 11 15 16 6 7 7 7 8 10 10 11 15 16 16 17 7 7 7 8 18 19 19 20 21 22 23 24 25 25 11 11 12 20 21 22 23 3 4 5 6 6 7 7 7 8 9 9 10 11 11 12 21 22 23 3 4 5 6 6 7 7 7 8 9 9 10 11 12 21 22 23 3 4 5 6 6 7 7 7 8 9 9 10 11 12 2 2 3 3 4 5 6 6 7 7 7 8 9 9 10 11 12 2 2 2 2 2 2 2 3 3 4 5 6 6 7 7 8 9 9 10 11 12 2 2 2 2 2 3 3 4 4 5 6 6 7 7 8 9 9 20 22 23 24 2 2 3 3 4 4 5 6 6 7 7 8 9 9 20 22 2 3 3 11 11 12 2 2 3 2 2 2 3 2 2 2 3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2	57424,90 47927,73 34193,45 54900,97 72239,56 82246,60 68935,51 50426,02 58923,02 77568,48 43654,84 61667,52 53728,40 47517,31 52047,12 28381,21 530426,02 4401,31 30151,15 104506,67 104506,67 104506,67 54520,37 59572,03 85844,91 58605,44 71043,012 446132,207 68845,071 58564,79 85844,91 58605,44 71043,012 46132,207 68845,071 54086,312 50266,088 54479,823 42985,521 66326,905 64340,369 92344,113 5569,7370 61015,018 5569,7371 45567,370 60156,018 66468,314 78571,401 55569,7911 45567,370 60156,018 66468,314 78571,401 55368,314 78571,401 55569,7911	ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.23 1545.36 1547.69 1541.87 1548.28 1550.83 1545.11 1542.03 1543.91 1553.44 1551.07 1545.36 1545.36 1545.36 1545.36 1547.39 1546.613 1539.703 1548.8926 1548.826 1549.627 1554.299 1546.758 1546.651 1555.109 1549.295 1540.621 1545.029 1549.479	/ 425.41 331.94 427.78 571.64 427.78 571.64 408.99 408.39 550.87 408.39 550.87 408.39 550.87 472.36 411.19 357.39 472.36 411.19 357.39 472.36 411.19 357.39 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.36 472.37 550.87 472.36 472.37 550.87 472.38 472.37 550.87 472.38 554.46 554.45 554.46 554.45 554.46 554.45 554.46 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 554.45 558.46 559.38 568.46 577.35 558.46 559.38 568.46 577.35 558.46 559.38 569	126.81 135.64 149.49 120.57 118.72 115.54 117.84 117.84 115.57 135.54 117.84 117.84 115.57 135.28 122.69 122.75 124.91 135.98 123.27 124.91 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 123.78 124.42 Г Г 116.610 121.391 120.52 124.42 Г Г 116.620 124.298 126.912 125.907 119.403 118.512 125.907 119.403 118.512 125.907 119.403 118.512 128.518 128.400 128.518 128.400 118.532 141.195 128.114 11.285 128.400 119.634 128.518 128.400 119.634 128.518 128.400 119.634 128.518 128.400 119.634 128.518 128.400 119.634 128.518 128.400 119.637 119	222197.93 213676.15 1111638.52 211734.95 267262.16 301891.86 279553.01 237783.89 218816.68 237636.14 143917.91 28379.46 214304.64 178619.52 186046.93 114231.68 220762.41 155102.07 205661.75 93319.03 349428.84 237780.54 172594.61 25842.883 243934.215 230293.18 A 268342.883 243934.215 31333.545 223180.211 206149.985 217591.742 212789.168 226844.821 270806.954 314876.463 243808.063 203145.443 21652.263 213719.492 256845.008 21552.2674 232568.947 232567.43 232567.	ω 1605.13 1605.58 1603.70 1604.82 1605.05 1605.05 1604.82 1605.05 1604.25 1604.25 1605.10 1605.26 1605.37 1605.66 1605.77 1605.61 1605.77 1605.61 1605.78 1606.11 1605.71 1606.11 1605.73 1606.11 1605.26 1604.61 1605.43 1604.613 1604.63 1604.63 1604.64 1605.28 1604.64 1605.28 1604.64 1605.28 1604.23 1604.23 1604.23 1604.23 1604.23 1604.23 1604.23 1604.23 1604.23 160	/ 3663.99 3403.98 1813.47 3467.64 4298.44 4993.08 4228.44 4993.08 3384.91 3384.91 3384.91 3384.91 3384.91 3384.91 3384.91 3474.76.24 3460.45 2845.53 3005.98 1810.25 2845.53 3005.98 1810.25 1650.90 5373.31 3713.64 2980.08 3804.51 3311.64 4927.163 389.462 3127.368 389.462 3127.368 3127.368 389.462 3127.368 3127.368 3127.368 3127.368 3127.368 3127.368 311.814 3316.406 5025.870 3318.462 5025.870 3318.468 5025.870 3318.468 5025.870 3318.468 5025.870 3318.468 5025.870 3318.468 3525.799 4038.229 4165.325 2915.146 3704.389 3525.799 4038.229 3310.440 3574.580 5055.426 3055.426 4963.220 4359.504	40.27 41.75 40.89 40.55 40.89 40.55 41.83 40.14 42.62 42.67 41.07 41.75 41.75 41.77 41.75 41.77 41.75 41.73 41.13 41.98 42.27 42.61 43.72 42.61 43.72 42.61 43.72 42.61 43.72 42.61 43.72 42.61 43.72 42.61 43.33 42.62 44.41 42.33 42.59 45.42 45.42 45.42 45.42 45.50 41.43 307 42.33 42.59 45.42 45.50 41.43 307 42.35 45.42 45.50 41.43 307 42.35 45.42 45.50 41.43 307 42.35 45.42 45.50 41.43 42.57 41.75 42.59 45.42 45.50 41.43 42.57 41.75 42.59 45.42 41.65 43.72 42.59 45.42 44.65 43.72 42.59 45.42 44.65 43.72 42.33 41.675 43.307 42.355 41.675 43.741 42.355 41.675 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.355 43.741 42.55 43.741 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 43.357 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.741 42.55 43.355 43.355 43.357 43.355 43.357 43.357 43.355 43.357 43.357 43.355 43.357 43

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 | Lorentziar
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| Facies

 | Sample | CM microtexture | | А
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 |
| Crinkly laminated chert

 | DI | Bitumen-like | 1 | 46109.808
 | 1627.318
 |
 | 24.915 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 2 | 57608.213
81163.559
 | 1626.641
 | 2151.683
 | 25.441
24.699 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 4 | 93574.661
 | 1623.625
 | 2067.600
 | 29.801 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 5 | 110950.990
101730.116
 | 1622.727
 | 2313.182
2290.850
 | 31.646
29.225 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 7 | 98738.463
 | 1624.010
 | 2188.244
 | 29.710 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 89 | 82641.228
118407.196
 | 1624.282
 | 1953.575
2571.134
 | 27.794
30.341 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 10 | 102360.795
 | 1623.556
 | 2216.096
 | 30.437 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 11 | 88126.586
 | 1623.699
 | 2007.864
 | 28.870 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 12 | 95363.448
83820.462
 | 1623.872
1624.025
 |
 | 28.428
29.207 | | | |
 | |
 |
| Crinkly laminated chert

 | D1
D1 | Bitumen-like | 14 | 104491.436
 | 1624,157
 | 2559.427
 | 26.792 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 15 | 82490.853
63522.875
 | 1626.255
1624.909
 | 2016.079
 | 26.861
27.301 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 17 | 141881.175
 | 1625.635
 | 3690.129
 | 25.190 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 18 | 78972.189
71615.932
 | 1626.361
1626.869
 | 2069.010 1890.165
 | 25.004
24.817 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 20 | 109813.280
 | 1625.800
 | 2583.016
 | 27.943 | | | |
 | |
 |
| Crinkly laminated chert
Crinkly laminated chert

 | D1
D1 | Bitumen-like
Bitumen-like | 21 | 77826.145
57721.293
 | 1627.169
 | 2131.118
 | 23.895
23.325 | | | |
 | |
 |
| Crinkly laminated chert

 | D1 | Bitumen-like | 23 | 96221.77
 | 1624.16
 | 2215.88
 | 28.57 | | | |
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 | Lorentziar
 | n (D2)
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| Facies

 | Sample | CM microtexture | | A
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 | Г | | | |
 | |
 |
| Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 1 | 46017.55
 | 1626.46
 | 1221.05
 | 24.67 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 2 | 22150.03
27970.44
 | 1620.28
1623.54
 | 434.98
598.16
 | 33.65
30.82 | | | |
 | |
 |
| Massive black chert

 | C9E | Bitumen-like | 4 | 15035.78
 | 1617.20
 | 293.62
 | 33.83 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 5
6 | 15179.21
27292.66
 | 1626.84
1626.92
 | 414.40
698.27
 | 23.97
25.63 | | | |
 | |
 |
| Massive black chert

 | C9E | Bitumen-like | 7 | 99472.825
 | 1624.747
 | 2398.142
 | 27.240 | | | |
 | |
 |
| Massive black chert

 | C9E | Bitumen-like | 8 | 11850.523
 | 1627.903
 | 261.296
 | 29.890 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 10 | 37799.193
18429.284
 | 1623.515
1625.407
 | 830.879
510.800
 | 29.951
23.588 | | | |
 | |
 |
| Massive black chert

 | C9E | Bitumen-like | 11 | 41155.769
 | 1628.075
 | 1024.930
 | 26.355 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Bitumen-like
Bitumen-like | 12
13 | 45012.994
28412.12
 | 1626.634
1624.72
 | 1280.696
713.94
 | 22.974
26.97 | | | |
 | |
 |
| Massive black chert

 | C9E | Bitumen-like | 14 | 70858.421
 | 1626.825
 | 1769.482
 | 26.276 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Interstitial
Interstitial | 15 | 54157.279
14929.826
 | 1624.787
 | 1364.438
 | 26.020
23.637 | | | |
 | |
 |
| Massive black chert

 | C9E | Interstitial | 17 | 60264.826
 | 1624.690
 | 1327.657
 | 29.902 | | | |
 | |
 |
| Massive black chert
Massive black chert

 | C9E
C9E | Cloudy
Cloudy | 18
19 | 14915.711
53089.834
 | 1628.996
1627.620
 | 449.751
1832.329
 | 21.650
18.844 | | | |
 | |
 |
| Massive black chert

 | C9E | Cloudy | 20 | 141881.175
 | 1625.635
 | 3690.129
 | 25.190 | | | |
 | |
 |
| Massive black chert

 | C9E | Cloudy | 21 | 53712.184
 | 1627.643
 | 1857.415
 | 18.807 | | | |
 | |
 |
| Massive black chert

 | C9E | Cloudy | 22 | 15703.651
 | 1626.691
 |
 | | | | |
 | |
 |
| Massive black chert

 | C9E | Cloudy | 23 | 14123.983
 | 1626.623
 | 532.811
479.619
 | 19.175
19.158 | | | |
 | |
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|

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 |
| Massive black chert Facies

 | C9E
Sample | Cloudy
CM microtexture | | 14123.983
R ₁
 | 1626.623
Γ _{D1/G}
 | 479.619

 | 19.158
A _D /A _G | R ₂ (1) | ΔT C° (2) | |
 | R _{D3} | R _{D4}
 |
| Massive black chert Facies Crinkly laminated chert

 | C9E Sample D1 | Cloudy
CM microtexture
Bitumen-like | 23 | 14123.983
R ₁
1.68
 | 1626.623
 | 479.619

 | 19.158
A _D /A _G
3.13 | 0.7255 | 318.17 | 304.85 | 366.07
 | 0.0947 | 0.0775
 |
| Massive black chert
Facies
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert

 | C9E Sample D1 | Cloudy
CM microtexture
Bitumen-like
Bitumen-like
Bitumen-like | 23
1
2
3 | 14123.983
R ₁
1.68
1.74
1.75
 | 1626.623
 | 479.619
 /(I_D1+I_G
0.6268
0.6356
0.6363
 | 19.158
A _D /A _G
3.13
3.39
3.31 | 0.7255
0.7306
0.7237 | 318.17
315.90
318.97 | 304.85
304.32
302.51 | 366.07
362.51
367.54
 | 0.0947
0.0997
0.0990 | 0.0775
0.0762
0.0809
 |
| Massive black chert
Facies
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert

 | C9E
Sample
D1
D1
D1
D1
D1 | Cloudy
CM microtexture
Bitumen-like
Bitumen-like
Bitumen-like
Bitumen-like | 23
1
2
3
4 | 14123.983
R ₁
1.68
1.74
1.75
1.98
 | 1626.623
 | 479.619
 (_D1+ _G
0.6268
0.6356
0.6363
0.6645
 | 19.158
A _D /A _G
3.13
3.39
3.31
3.86 | 0.7255
0.7306
0.7237
0.7290 | 318.17
315.90
318.97
316.61 | 304.85
304.32
302.51
305.49 | 366.07
362.51
367.54
332.95
 | 0.0947
0.0997
0.0990
0.0955 | 0.0775
0.0762
0.0809
0.0740
 |
| Massive black chert
Facies
Crinkly laminated chert
Crinkly laminated chert
Crinkly laminated chert

 | C9E
Sample
D1
D1
D1
D1
D1
D1 | Cloudy
CM microtexture
Bitumen-like
Bitumen-like
Bitumen-like | 23
1
2
3
4
5
6 | 14123.983
R ₁
1.68
1.74
1.75
1.98
2.00
1.95
 | 1626.623
Γ _{D1/G} 1.89 1.97 1.92 1.98 1.93 2.05
 | 479.619
ID1/(ID1+IG
0.6268
0.6356
0.6363
0.6645
0.6664
0.6607
 | 19.158
A _D /A _G
3.13
3.39
3.31
3.86
3.79
3.92 | 0.7255
0.7306
0.7237
0.7290
0.7317
0.7330 | 318.17
315.90
318.97
316.61
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| Laminated black chert
Laminated black chert | C2C
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 | Grain
Grain | 1
 | 110888.27
133780.70 | 1195.16
 | 401.73 393.05
 | 209.69 | 714507.90
642000.06
 | 1356.33 | 8005.59
7138.29 | 59.28
59.76 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 3
 | 74280.81
84303.25 | 1177.52
1187.84
 | 266.75
369.96
 | 213.45
167.13 | 370808.96
692698.96
 | 1356.60
1356.74 | 4479.16
8013.66 | 54.81
57.33 |
| Laminated black chert | C2C

 | Grain | 5
 | 141702.82 | 1195.54
 | 510.81
 | 210.94 | 903186.90
 | 1356.43 | 9369.25
10794.74 | 64.27 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 6 7
 | 134078.29
148409.62 | 1191.95
1197.91
 | 561.60
556.18
 | 176.33
201.03 | 1025870.00
886707.92
 | 1356.51
1356.13 | 8806.43 | 63.31
67.27 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 8
 | 101128.99
94040.30 | 1192.61
1196.41
 | 409.04
412.04
 | 183.75
167.03 | 723511.31
736152.37
 | 1356.60
1356.41 | 7848.08
7918.25 | 61.33
61.87 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 10
 | 91210.73
75658.61 | 1193.33
1196.05
 | 430.02
303.90
 | 153.54
185.08 | 781551.46
502913.07
 | 1356.56
1356.75 | 8016.25
5286.02 | 65.03
63.39 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 12
 | 113570.42
81221.90 | 1188.19
1204.90
 | 490.63
350.32
 | 170.22 | 875042.19
615411.84
 | 1356.42 | 9913.66
6693.75 | 58.60 |
| Laminated black chert | C2C

 | Grain | 14
 | 85691.64 | 1200.56
 | 327.54
 | 196.12 | 569783.61
 | 1356.55 | 6492.96 | 58.25 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 15
 | 107487.74
55063.12 | 1203.91
1188.30
 | 374.85
240.78
 | 219.05
167.81 | 619027.89
376339.21
 | 1357.15
1357.09 | 6963.57
4361.01 | 59.04
57.24 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 17
 | 122290.35
63959.04 | 1202.73
1198.46
 | 408.26
273.82
 | 231.33
171.53 | 681324.07
462545.55
 | 1357.00 | 7698.50
5286.24 | 58.76
58.07 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Grain | 19
20
 | 112394.81
51992.10 | 1190.23
1179.28
 | 382.53
257.14
 | 226.94
145.86 | 637699.27
350733.61
 | 1357.48
1356.92 | 7399.50
3908.49 | 57.16
59.62 |
| Laminated black chert | C2C

 | Grain | 21
 | 157322.40 | 1197.44
 | 643.15
 | 181.17 | 1074650.00
 | 1356.49 | 11028.91 | 64.99
59.49 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Grain
Bituminous-XcV | 22
 | 127200.13
93552.93 | 1194.63
1203.42
 | 430.16
370.23
 | 228.35
187.97 | 733657.60
520298.20
 | 1356.95
1355.42 | 8193.53
4588.67 | 76.26 |
| Laminated black chert
Laminated black chert | C2C
C2C

 | Bituminous-XcV
Bituminous-XcV | 24
25
 | 105770.04
102173.56 | 1203.83
1203.21
 | 410.28
414.18
 | 192.50
182.68 | 660841.26
591957.86
 | 1355.10
1355.23 | 5817.20
4685.97 | 76.41
85.55 |
| <u>_</u> . |

 | |
 | | Lorentzian
 | (D4)
 | _ |
 | Lorentzian | (D1) | |
| Facies
Granular carbonaceous chert | D4A

 | CM microtexture
Mats-like network | 1
 | A
146783.25 | ω
1199.64
 | 530.22
 | Г
210.31 | A
921251.526
 | <u>ω</u>
1356.435 | 1
10782.531 | Г
56.653 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 2
 | 94290.10
156880.63 | 1193.20
1197.04
 | 386.52
571.90
 | 180.97
208.17 | 664291.674
997801.984
 | 1356.706
1356.511 | 7643.005
11691.717 | 57.675
56.587 |
| Granular carbonaceous chert | D4A

 | Mats-like network | 4
 | 108416.82 | 1213.15
 | 408.14
 | 199.18 | 688799.584
 | 1356.628 | 8041.664 | 56.802 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 5
 | 83519.13
111076.88 | 1198.88
1200.32
 | 358.46
412.69
 | 171.13
203.18 | 621021.756
721823.561
 | 1356.852
1356.973 | 7140.186
8637.836 | 57.717
55.358 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 7
 | 106863.06 144162.04 | 1196.18
1195.22
 | 377.93
531.29
 | 216.13
205.55 | 631045.161
914167.588
 | 1357.015
1357.079 | 7448.779
10851.579 | 56.155
55.826 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 9
 | 126868.79
187812.78 | 1195.55
1207.98
 | 474.91
621.71
 | 201.66
233.61 | 809623.385
1038100.000
 | 1356.897
1356.740 | 9322.197
12140.436 | 57.629
56.701 |
| Granular carbonaceous chert | D4A

 | Mats-like network | 11
 | 123236.22 | 1204.10
 | 401.39
 | 238.75 | 743436.031
 | 1356.852 | 8872.571 | 55.514 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 12
 | 90632.40
109637.56 | 1202.02
1199.33
 | 333.03
378.78
 | 205.81
222.20 | 592336.070
672528.875
 | 1357.180
1357.083 | 7081.274
7956.220 | 55.416
56.024 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Mats-like network
Mats-like network | 14
 | 148483.17
135801.09 | 1207.82
 | 456.68
 | 256.43 | 773798.586
848006.545
 | 1357.150 | 9522.561
10074.487 | 53.768
55.779 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain
Grain | 16
17
 | 99741.27
132189.94 | 1193.91
1202.52
 | 357.76
452.93
 | 212.58
224.23 | 591926.820
727238.593
 | 1356.211
1356.294 | 6186.134
7760.763 | 63.780
62.398 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain
Grain | 18
19
 | 109305.09
113713.90 | 1199.09
1191.69
 | 442.35
509.70
 | 183.42
162.99 | 728837.847
808783.656
 | 1355.930
1355.233 | 7655.861
8044.657 | 63.440
67.181 |
| Granular carbonaceous chert | D4A

 | Grain | 20
 | 106976.17 | 1200.96
 | 422.36
 | 188.80 | 662559.132
 | 1355.671 | 6024.937 | 73.847 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain
Grain | 21
22
 | 122802.80
111949.68 | 1198.78
1194.31
 | 451.34
396.17
 | 205.98
216.10 | 712860.129
685300.550
 | 1356.478
1356.408 | 7060.681
7286.141 | 67.480
62.641 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain
Grain | 23
24
 | 164055.09
188864.21 | 1198.60
1204.81
 | 607.97
609.07
 | 203.93
241.70 | 1027530.000
1062840.000
 | 1356.530
1356.996 | 10380.126
12314.596 | 66.095
57.254 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain
Grain | 25
26
 | 128147.05
92727.16 | 1194.82
1195.82
 | 483.11
303.11
 | 199.99
238.47 | 836373.175
508730.144
 | 1357.060
1356.608 | 9241.888
5553.282 | 60.162
60.935 |
| Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain | 27
28
 | 184386.38
123427.00 | 1203.06
 | 633.11
524.02
 | 223.60
173.17 | 1046230.000
950268.657
 | 1356.631
1356.309 | 11551.635
9695.531 | 60.212
65.408 |
| Granular carbonaceous chert
Granular carbonaceous chert
Granular carbonaceous chert | D4A
D4A

 | Grain | 29
 | 130148.59 | 1198.61
 | 472.61
 | 207.76 | 793165.725
 | 1356.291 | 8307.966 | 64.510 |
| |

 | |
 | | 1100 54
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 | 200 47 | 000004.000
 | 1256 422 | 0122 705 | |
| |

 | Grain | 30
 | 141628.83 | 1198.54
Gaussian
 | 519.02
(D3)
 | 206.47 | 862604.259
 | 1356.432
Lorentziar | 9133.785
n (G) | 63.429 |
| Facies | Sample

 | CM microtexture |
 | A | Gaussian
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 | Г | A
 | Lorentziar
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| Facies
Laminated black chert
Laminated black chert | Sample
C2C
C2C

 | CM microtexture
Grain
Grain | 1
 | A
57424.90
47927.73 | Gaussian
<u> </u>
1550.35
1547.03
 | (D3)
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331.94
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126.81
135.64 | A
222197.93
213676.15
 | Lorentziar
<u> </u> | r (G)
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3663.99
3403.98 | Г
40.27
41.75 |
| Facies
Laminated black chert
Laminated black chert
Laminated black chert
Laminated black chert | Sample
C2C

 | CM microtexture
Grain | 1
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57424.90
47927.73
34193.45
54900.97 | Gaussian
<u>w</u>
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1547.03
1555.40
1552.42
 | (D3)
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 | Lorentziar | n (G)
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| Facies
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Laminated black chert
Laminated black chert
Laminated black chert
Laminated black chert | Sample
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 | CM microtexture
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34193.45 | Gaussian
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571.64
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149.49
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118.72 | A
222197.93
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 | Lorentziar | r (G)
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| Facies
Laminated black chert
Laminated black chert
Laminated black chert
Laminated black chert
Laminated black chert
Laminated black chert | Sample C2C

 | CM microtexture
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68935.51 | Gaussian
<u>w</u>
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 | Г
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| Facies
Laminated black chert
Laminated black chert | Sample C2C

 | CM microtexture
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 | Lorentziar
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1604.25 | / 3663.99 3403.98 1813.47 3467.64 4248.44 4993.08 4296.20 3714.13 3384.91 51.51 | 40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 |
| Facies
Laminated black chert
Laminated black chert | Sample C2C

 | CM microtexture
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| Facies Laminated black chert | Sample C2C

 | CM microtexture
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61687.52 | Gaussian ω 1550.35 1547.03 1555.40 1552.42 1545.23 1545.23 1545.23 1545.38 1545.59 1551.69 1547.69 1541.87 1548.88
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Lorentziar | / 3663.99 3403.98 813.47 3467.64 4248.44 4296.20 3714.13 3384.91 3384.91 3881.34 2345.87 4476.24 3460.45 | 40.27 41.75 40.89 40.55 41.83 40.14 43.35 42.62 43.04 40.68 40.75 42.27 |
| Facies Laminated black chert | Sample C2C

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| Facies Laminated black chert | Sample C2C

 | CM microtexture
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 | Image: constraint of the system 40.27 40.74 41.75 41.75 41.75 41.83 40.55 41.83 40.75 42.62 43.04 40.68 40.75 42.27 41.175 41.13 42.27 41.13 42.27 41.13 42.28 43.32 42.28 43.32 42.28 43.33 42.63 42.63 42.63 42.63 42.63 42.63 42.63 42.63 42.63 42.63 42.63 43.361 43.362 41.022 44.441 42.362 42.363 41.734 42.363 42.363 41.734 |

					Lorentzian	(D2)							
Facies	Sample	CM microtexture		A	ω	1	Г						
Laminated black chert Laminated black chert	C2C C2C	Grain Grain	2	53975.93 45750.31	1628.59 1629.22	1540.26 1276.56	22.90 23.44						
Laminated black chert	C2C	Grain	3	37991.97	1626.56	1001.30	24.84						
Laminated black chert Laminated black chert	C2C C2C	Grain Grain	4	61724.48 102127.76	1627.86 1625.60	1670.15 2342.13	24.18 28.67	1					
Laminated black chert	C2C	Grain	6	101924.17	1627.08	2552.98	26.18						
Laminated black chert	C2C	Grain	7	78021.94	1626.74	1973.40	25.92						
Laminated black chert Laminated black chert	C2C C2C	Grain Grain	8	53250.64 78328.24	1628.72 1626.54	1523.28	22.84 28.82						
Laminated black chert	C2C	Grain	10	76531.72	1627.93	1872.32	26.83						
Laminated black chert Laminated black chert	C2C C2C	Grain Grain	11	55958.17 79854.20	1626.30 1627.52	1316.99 2033.58	27.92 25.74	1					
Laminated black chert	C2C	Grain	13	51437.73	1628.65	1445.74	23.26						
Laminated black chert Laminated black chert	C2C	Grain	14	50436.91	1627.62	1299.49	25.43						
Laminated black chert	C2C C2C	Grain Grain	16	62997.54 29374.57	1627.23 1628.34	1556.13 765.01	26.56 25.16	1					
Laminated black chert	C2C	Grain	17	55938.41	1628.58	1575.09	23.22			Lege			
Laminated black chert Laminated black chert	C2C C2C	Grain Grain	18	37358.17 59606.96	1628.70 1628.32	1058.20 1565.43	23.07			A = integra ω = peak p			
Laminated black chert	C2C	Grain	20	38649.54	1627.33	954.21	26.58			I = peak in			
Laminated black chert	C2C	Grain	21	80041.09	1628.08	2105.88	24.89		$\Gamma = FWH$	M (full widt	h half ma	ximum)	
Laminated black chert Laminated black chert	C2C C2C	Grain Bituminous-XcV	22 23	57781.75 43503.44	1628.91 1626.51	1542.77 1068.27	24.52 26.72	(1) R	$_{2} = A_{D1} / (A_{D})$	$A_{D1} + A_{D2} + A_{D2}$	_G) (Beyss	ac et al., 20	002)
Laminated black chert	C2C	Bituminous-XcV	24	46346.92	1626.33	1214.56	24.99	(2) T_	_115*D2	641 (1-50	°C) (Boyr	sac et al., 2	2002)
Laminated black chert	C2C	Bituminous-XcV	25	35242.59	1627.07	976.77	23.59	(2) 1=	-443°KZ +	041 (+-30	C) (Beys		
Eccion	Comple	CM microtoxturo			Lorentzian	(DZ)	<i>_</i>	(3) T=	-2,15 (FW	'HM-D1)+47	'8 (Kouke	etsu et al., 2	2014)
Facies Granular carbonaceous chert	D4A	CM microtexture Mats-like network	1	A 84251.654	ω 1627.099	2192.836	25.177						
Granular carbonaceous chert	D4A	Mats-like network	2	53498.965	1627.625	1455.017	24.064	(4) T=	-6,78 (FW	HM-D2)+53	5 (Kouke	tsu et al., 2	2014)
Granular carbonaceous chert Granular carbonaceous chert	D4A	Mats-like network	3	85193.678 69082.625	1627.538	2211.336	25.249		(5) R _{D3} =	= I _{D3} /I _{D1} (Sf	orna et al	., 2014)	
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Mats-like network Mats-like network	4	50455.056	1627.019 1627.976	1650.530 1331.472	27.500 24.824			= I _{D4} /I _{D1} (Sf			
Granular carbonaceous chert	D4A	Mats-like network	6	81966.548	1625.870	1989.065	27.058		(0) K _{D4} =	- 1 _{D4} / 1 _{D1} (ST	una et al	., 2014)	
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Mats-like network Mats-like network	7	56900.244 75440.499	1627.614	1448.573 2045.143	25.759 24.146						
Granular carbonaceous chert	D4A	Mats-like network	9	63071.518	1628.269	1770.689	23.293	1					
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Mats-like network Mats-like network	10	103228.710 69043.266	1626.492	2565.675 1781.196	26.400 25.407						
Granular carbonaceous chert	D4A	Mats-like network	12	47189.981	1628.316	1272.426	24.280						
Granular carbonaceous chert	D4A	Mats-like network	13	59944.481	1627.523	1547.866	25.385						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Mats-like network Mats-like network	14 15	71595.384 74773.736	1627.177	1894.054 1992.426	24.758 24.576						
Granular carbonaceous chert	D4A	Grain	16	49201.862	1626.287	1286.002	25.065						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Grain Grain	17 18	62843.012 75405.227	1625.316 1626.796	1578.037 1699.365	26.118 29.212						
Granular carbonaceous chert	D4A	Grain	19	69625.113	1626.906	1788.476	25.519						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Grain Grain	20 21	57883.323 59205.350	1626.756 1627.054	1399.943 1528.821	27.155 25.382						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Grain	22	58815.018	1627.034	1526.621	25.003						
Granular carbonaceous chert	D4A	Grain	23	105505.457	1627.098	2493.124	27.816						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A	Grain Grain	24 25	103129.403 65205.076	1625.887 1627.373	2483.408 1683.067	27.274 25.394						
Granular carbonaceous chert	D4A	Grain	26	40821.152	1627.186	1090.512	24.510						
Granular carbonaceous chert	D4A	Grain	27	130883.813	1624.996	2878.699	29.949						
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert	D4A D4A D4A	Grain Grain Grain											
Granular carbonaceous chert	D4A	Grain	27 28	130883.813 93238.443	1624.996 1626.372	2878.699 2131.664	29.949 28.779						
Granular carbonaceous chert Granular carbonaceous chert	D4A D4A D4A	Grain Grain	27 28 29	130883.813 93238.443 74990.048	1624.996 1626.372 1626.728 1626.606	2878.699 2131.664 1817.172 1925.822	29.949 28.779 26.921 26.251	R ₂ (1)	<u>ΔT C° (2)</u>	<mark>ΔΤ C° (3)</mark>	<mark>\T C° (4</mark>	R _{D3}	R _{D4}
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Facies Laminated black chert	D4A D4A D4A Sample C2C	Grain Grain Grain CM microtexture Grain	27 28 29 30	130883.813 93238.443 74990.048 77585.568 R ₁ 2.18	1624.996 1626.372 1626.728 1626.606 Гр1/G	2878.699 2131.664 1817.172 1925.822 ID1/(ID1+IG 0.6860	29.949 28.779 26.921 26.251 AD/AG 3.22	0.7212	320.05	351.54	379.74	0.0531	0.0502
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Facies	D4A D4A D4A Sample	Grain Grain Grain CM microtexture	27 28 29	130883.813 93238.443 74990.048 77585.568 R ₁	1624.996 1626.372 1626.728 1626.606	2878.699 2131.664 1817.172 1925.822 ID1/(ID1+IG 0.6860 0.6771 0.7118	29.949 28.779 26.921 26.251 A _D /A _G	0.7212 0.7122 0.7125					
Granular carbonaceous chert Granular carbonaceous chert Facies Laminated black chert Laminated black chert Laminated black chert Laminated black chert	D4A D4A D4A Sample C2C C2C C2C C2C	Grain Grain Crain CM microtexture Grain Grain Grain Grain	27 28 29 30 1 1 2 3 4	130883.813 93238.443 74990.048 77585.568 R ₁ 2.18 2.10	1624.996 1626.372 1626.728 1626.606 Гри/с 1.47 1.43 1.34 1.34	2878.699 2131.664 1817.172 1925.822 ID1/(ID1+IG 0.6860 0.6771 0.7118 0.6980	29.949 28.779 26.921 26.251 A _D /A _G 3.22 3.00	0.7212 0.7122 0.7125 0.7170	320.05 324.07 323.94 321.95	351.54 350.51 361.16 355.73	379.74 376.11 366.56 371.03	0.0531 0.0465 0.0480 0.0534	0.0502 0.0551 0.0596 0.0462
Granular carbonaceous chert Granular carbonaceous chert Facies Laminated black chert Laminated black chert Laminated black chert Laminated black chert Laminated black chert Laminated black chert	D4A D4A D4A Sample C2C C2C C2C C2C C2C C2C C2C C2C	Grain Grain Crain CM microtexture Grain Grain Grain Grain Grain Grain	27 28 29 30 1 1 2 3 4 5 6	130883.813 93238.443 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21 2.21 2.16	1624.996 1626.372 1626.728 1626.606 F D1/G 1.47 1.43 1.34 1.41 1.54 1.58	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6980 0.6880 0.6837	29.949 28.779 26.921 26.251 A _D /A _G 3.22 3.00 3.32 3.27 3.38 3.40	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175	320.05 324.07 323.94 321.95 325.17 321.69	351.54 350.51 361.16 355.73 340.83 342.88	379.74 376.11 366.56 371.03 340.60 357.48	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Eacles Laminated black chert Laminated black chert Laminated black chert Laminated black chert	D4A D4A D4A Sample C2C C2C C2C C2C C2C	Grain Grain Crain Cmortexture Grain Grain Grain Grain	27 28 29 30 1 1 2 3 4 5	130883.813 93238.443 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21	1624.996 1626.372 1626.728 1626.606 1.47 1.47 1.43 1.34 1.41 1.54	2878.699 2131.664 1817.172 1925.822 Ib_/(Ib_1+Ic 0.6860 0.6771 0.7118 0.6980 0.6880	29.949 28.779 26.921 26.251 A _D /A _G 3.22 3.00 3.32 3.27 3.38	0.7212 0.7122 0.7125 0.7170 0.7097	320.05 324.07 323.94 321.95 325.17	351.54 350.51 361.16 355.73 340.83	379.74 376.11 366.56 371.03 340.60	0.0531 0.0465 0.0480 0.0534 0.0610	0.0502 0.0551 0.0596 0.0462 0.0545
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A Sample C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	27 28 29 30 1 2 3 3 4 4 5 6 6 7 7 8 9	130883.813 93238.443 74990.048 77585.568 <u>R1</u> 2.18 2.10 2.47 2.31 2.21 2.16 2.05 2.11 2.34	1624.996 1626.372 1626.728 1626.606 1.47 1.43 1.34 1.43 1.34 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6980 0.6880 0.6887 0.6721 0.6788 0.6788	29.949 28.779 26.921 26.251 AD/AG 3.22 3.00 3.32 3.27 3.38 3.40 3.17 3.04 3.36	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7126 0.7131 0.7124	320.05 324.07 323.94 321.95 325.17 321.69 323.88 323.65 323.97	351.54 350.51 361.16 355.73 340.83 342.88 334.36 347.15 345.98	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0624 0.0522 0.0516	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0632 0.0632 0.0521 0.0520
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	27 28 29 30 1 2 3 4 4 5 6 6 7 7 8 9 10 11	130883.813 93238.443 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.16 2.05 2.11 2.34 2.07 2.25	1624.996 1626.372 1626.728 1626.606 1.47 1.43 1.34 1.43 1.54 1.55 1.44 1.58 1.55 1.44 1.60 1.56	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6980 0.6837 0.6721 0.6721 0.6788 0.7005 0.6738 0.6738	29.949 28.779 26.251 26.251 A_D/A_G 3.22 3.00 3.32 3.27 3.38 3.40 3.17 3.04 3.36 3.29 3.49	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7126 0.7131 0.7124 0.7133 0.7156	320.05 324.07 323.94 321.95 325.17 321.69 323.88 323.65 323.97 323.59 322.56	351.54 350.51 361.16 355.73 340.83 342.88 334.36 347.15 345.98 339.18 339.18 342.72	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10 345.72	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0624 0.0522 0.0516 0.0687 0.0648	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0632 0.0521 0.0520 0.0520 0.0536 0.0575
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain CM microtexture Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	27 28 29 30 1 2 3 4 4 5 5 6 7 7 8 9 10	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.47 2.31 2.21 2.16 2.16 2.05 2.11 2.34 2.07	1624.996 1626.372 1626.728 1626.606 1.47 1.47 1.43 1.34 1.41 1.54 1.55 1.55 1.44 1.41	2878.699 2131.664 1817.172 1925.822 Ib_1/(Ib_1+Ic 0.6860 0.6771 0.7118 0.6980 0.6887 0.6781 0.6788 0.7005 0.6738	29.949 28.779 26.921 26.251 3.22 3.00 3.32 3.27 3.38 3.40 3.17 3.04 3.36 3.29	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7126 0.7131 0.7124 0.7133	320.05 324.07 323.94 321.95 325.17 321.69 323.88 323.65 323.97 323.59	351.54 350.51 361.16 355.73 340.83 342.88 334.36 347.15 345.98 339.18	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0624 0.0522 0.0516 0.0687	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0632 0.0521 0.0520 0.0520 0.0536
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Eacies Laminated black chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain CM microtexture Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	27 28 29 30 1 1 2 3 4 4 5 6 6 7 7 8 9 10 11 11 12 12 13 14	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.23 2.21 1.93 2.28	1624.996 1626.372 1626.728 1626.606 1626.606 1.47 1.47 1.43 1.34 1.54 1.55 1.55 1.44 1.60 1.56 1.56 1.56 1.49 1.49 1.40	2878.699 2131.664 1817.172 1925.822 197.(101+16 0.6860 0.6771 0.67118 0.6680 0.6680 0.6680 0.6687 0.6682 0.6682 0.6692 0.6692 0.6692	29.949 28.792 26.921 26.251 3.22 3.00 3.22 3.00 3.22 3.27 3.38 3.40 3.17 3.04 3.36 3.29 3.29 3.08 3.08 2.87 3.19	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7126 0.7131 0.7124 0.7133 0.7156 0.7061 0.6984 0.7133	320.05 324.07 323.94 321.95 325.17 321.69 323.88 323.65 323.97 323.59 322.56 326.79 320.21 323.60	351.54 350.51 361.16 355.73 340.83 342.88 334.36 347.15 345.98 339.18 342.72 353.01 347.52 353.77	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10 345.72 360.48 377.30 362.56	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0622 0.0516 0.0687 0.0648 0.0648 0.0476 0.0648	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0632 0.0521 0.0521 0.0520 0.0536 0.0575 0.0495 0.0523 0.0554
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Eacies Laminated black chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain CM microtexture Grain	27 28 29 30 1 1 2 3 4 5 5 6 6 6 7 7 8 9 10 11 12 13 14 15 16	130883.813 93238.443 74990.048 77585.568 2.18 2.18 2.10 2.47 2.31 2.16 2.05 2.11 2.34 2.07 2.23 2.21 1.93 2.28 2.32 2.32 2.32 2.34	1624.996 1626.372 1626.728 1626.606 1.47 1.47 1.43 1.34 1.54 1.55 1.44 1.58 1.55 1.44 1.60 1.56 1.39 1.49 1.49 1.40 1.36	2876.699 2131.664 1817.172 1925.822 1925.822 0.6860 0.6771 0.67718 0.6880 0.6837 0.6788 0.66837 0.6788 0.6728 0.6788 0.6728 0.6738 0.6952 0.6889 0.6592 0.6895 0.6955	29,949 28,799 26,921 26,251 3,22 3,000 3,322 3,27 3,300 3,327 3,27 3,340 3,17 3,04 3,36 3,29 3,36 3,29 3,08 2,87 3,19 3,33 3,29	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7126 0.7131 0.7124 0.7133 0.7156 0.7061 0.6984 0.7133 0.7131 0.7133	320.05 324.07 323.94 321.95 325.17 321.69 323.88 323.65 323.97 323.59 322.56 326.79 330.21 323.60 323.67 323.67 318.91	351.54 350.51 361.16 355.73 340.83 342.88 334.36 347.15 345.98 339.18 342.72 353.01 347.52 353.77 355.94	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10 345.72 360.48 377.30 362.56 354.91 364.44	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0622 0.0516 0.0687 0.0648 0.0476 0.0648 0.0476 0.0614 0.0550 0.0516 0.0516	0.0502 0.0551 0.0596 0.0462 0.0520 0.0520 0.0520 0.0520 0.0522 0.0522 0.0523 0.0523 0.0523 0.0553 0.0554
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Crain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain Grain	27 28 29 30 1 1 2 3 4 4 5 5 6 7 7 8 8 9 10 11 12 12 13 14 15 16 17	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.16 2.05 2.05 2.07 2.25 2.21 1.93 2.25 2.21 1.93 2.28 2.28 2.28 2.28 2.28 2.32 2.41 2.22	$\begin{array}{c} 1624.996\\ 1626.372\\ 1626.728\\ 1626.728\\ 1626.606\\ \hline\\ 1.47\\ 1.43\\ 1.34\\ 1.41\\ 1.54\\ 1.58\\ 1.55\\ 1.55\\ 1.44\\ 1.66\\ 1.56\\ 1.39\\ 1.49\\ 1.40\\ 1.44\\ 1.36\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.40\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ 1.39\\ 1.36\\ $	2878.699 2131.664 1817.172 1925.822 1925.822 0.68860 0.6877 0.67711 0.67880 0.6887 0.66880 0.66781 0.67788 0.6788 0.6788 0.6788 0.6788 0.6788 0.6788 0.6788 0.6788 0.6788 0.66859 0.66852 0.6885 0.6885 0.7067 0.6885	29,949 28,779 26,921 26,251 3,22 3,00 3,32 3,27 3,38 3,40 3,340 3,340 3,340 3,340 3,349 3,04 3,304 3,304 3,287 3,04 3,304 3,304 3,304 3,304 3,304 3,305 3,309	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7176 0.7131 0.7131 0.7134 0.7133 0.7133 0.7133 0.7133 0.7133 0.7133 0.7131 0.7131 0.7238	320.05 323.94 321.95 325.17 321.69 323.88 323.65 323.97 322.56 322.56 326.79 330.21 323.60 323.60 323.67 323.60 323.67	351.54 350.51 361.16 355.73 342.88 334.36 347.15 345.98 339.18 342.72 353.01 347.52 353.77 352.07 355.94 352.66	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10 345.72 360.48 377.30 362.56 354.91 364.44 377.60	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0522 0.0516 0.0687 0.0648 0.0476 0.0614 0.0550 0.0516 0.0496 0.0496	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0520 0.0521 0.0520 0.0523 0.0522 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0523 0.0554
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A Sample C2C	Grain Grain Grain CM microtexture Grain	27 28 29 30 1 1 2 3 3 4 5 6 6 7 7 7 8 9 9 10 11 112 13 14 15 16 17 18 19	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.16 2.05 2.11 2.34 2.07 2.25 2.21 1.33 2.25 2.21 1.33 2.28 2.23 2.24 2.32 2.41 2.22 2.24 2.22 2.24 2.27	$\begin{array}{c} 1624.996\\ 1626.372\\ 1626.728\\ 1626.728\\ 1626.606\\ \hline\\ \hline\\ \hline\\ \hline\\ 1.47\\ 1.43\\ 1.41\\ 1.54\\ 1.58\\ 1.55\\ 1.55\\ 1.44\\ 1.44\\ 1.58\\ 1.59\\ 1.39\\ 1.39\\ 1.49\\ 1.40\\ 1.44\\ 1.36\\ 1.39\\ 1.33\\ 1.36\\ 1.33\\ 1.36\\ 1.36\\ 1.33\\ 1.36\\ 1.36\\ 1.33\\ 1.36\\ 1.36\\ 1.33\\ 1.36\\ 1.36\\ 1.32\\ 1.33\\ 1.36\\ 1.3$	2876.699 2131.664 1817.172 1925.822 bp1/(lp1+lg 0.6880 0.6771 0.7118 0.6880 0.6683 0.6782 0.6782 0.6782 0.6783 0.6782 0.66935 0.66935 0.66935 0.66935 0.66935 0.66935 0.66935 0.66935	29,949 28,779 26,921 26,251 A _D /A _G 3.22 3.00 3.32 3.27 3.33 3.40 3.340 3.40 3.340 3.40 3.40 3.	0.7212 0.7122 0.7125 0.7170 0.7097 0.70175 0.7175 0.7175 0.7131 0.7124 0.7133 0.7136 0.7133 0.7136 0.7131 0.7136 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7155 0.7165 0.7175 0	320.05 323.94 321.95 325.17 321.69 323.88 323.65 323.65 323.97 322.56 322.56 326.79 330.21 323.60 323.67 323.67 323.67 323.67 323.67 326.75 326.75	351.54 350.51 361.16 355.73 340.83 344.88 344.88 344.88 344.88 344.88 344.88 344.88 344.88 344.88 344.88 344.98 344.98 345.98 345.98 345.91 355.94 355.94 355.94 355.94 355.94 355.66 356.11	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 353.10 355.26 330.13 345.72 360.48 377.30 362.56 354.91 378.56 354.91 378.56 364.44 377.50	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0622 0.0522 0.0516 0.0648 0.0648 0.0648 0.0648 0.0648 0.0648 0.0648 0.0614 0.0550 0.0516 0.0535 0.0465	0.0502 0.0551 0.0556 0.0462 0.0545 0.0520 0.0521 0.0520 0.0522 0.0522 0.0525 0.0523 0.0575 0.0495 0.0523 0.0554 0.0538 0.0554 0.0538 0.05552 0.0530 0.0517
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A Sample C2C	Grain Grain Grain CM microtexture Grain	27 28 30 1 1 2 3 3 4 4 5 6 7 7 8 9 10 11 12 13 14 15 16 17 17 18 19 20 22 12	130883.813 93238.443 774990.048 77585.568 R 1 2.18 2.10 2.47 2.21 2.31 2.21 2.31 2.21 2.31 2.21 2.31 2.25 2.21 1.93 2.22 2.41 2.22 2.41 2.22 2.41 2.22 2.24 2.22 2.24 2.27 2.37 2.05	$\begin{array}{c} 1624.996\\ 1626.322\\ 1626.728\\ 1626.606\\ \hline\\ \hline\\ \hline\\ \hline\\ \hline\\ \hline\\ \hline\\ \hline\\ 1.47\\ 1.58\\ 1.57\\ 1.58\\ 1.59\\ 1.44\\ 1.44\\ 1.44\\ 1.44\\ 1.36\\ 1.39\\ 1.33\\ 1.36\\ 1.59\\ 1.59\\ 1.59\\ 1.59\\ 1.59\\ 1.50\\ 1.59\\ 1.59\\ 1.50\\ 1.50\\ 1$	2876.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6880 0.6880 0.6683 0.6782 0.6782 0.6782 0.6782 0.6783 0.6782 0.6783 0.6783 0.6885 0.6771 0.6771 0.6885 0.6885 0.6772 0.6885 0.6772 0.6885 0.6772 0.6885 0.6772 0.6772 0.6885 0.6775 0.6772 0.6775 0.6885 0.6775 0.6775 0.6885 0.6775 0.6775 0.6775 0.6885 0.6775 0.6775 0.6885 0.6775 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6775 0.6885 0.6975 0.67750 0.67750 0.67750 0.67750000000000000000000000000000000000	29,949 28,779 26,921 26,221 26,251 A₀/A₆ 3,22 3,30 3,32 3,27 3,340 3,17 3,04 3,34 3,34 3,34 3,34 3,34 3,34 3,34	0.7212 0.7125 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7134 0.7134 0.7134 0.7134 0.7135 0.7135 0.7135 0.7131 0.7134 0.7131 0.7735 0.7131 0.7735 0.7731 0.7712 0.7762 0.7726 0.77270 0.77270 0.772700000000000000000	320.05 324.07 323.94 321.95 325.17 323.88 323.65 323.97 323.59 322.56 326.79 330.21 323.60 323.67 323.60 323.67 326.75 326.75 326.75 326.75 326.75 326.75 326.75	351.54 350.51 361.16 355.73 340.83 342.88 334.28 347.15 345.98 339.18 347.15 353.01 347.52 353.01 347.52 353.77 355.94 352.06 352.66 354.15 356.81 350.82	379.74 376.11 366.56 371.03 340.60 357.48 359.26 339.61 353.10 345.72 360.48 377.30 362.56 354.91 364.41 377.60 377.50 364.41 377.60 378.56 365.91 354.82 366.23	0.0531 0.0465 0.0480 0.0534 0.0610 0.0620 0.0622 0.0522 0.0516 0.0642 0.0648 0.0476 0.0648 0.0476 0.0550 0.0648 0.0476 0.0535 0.0465 0.0465 0.0465	0.0502 0.0551 0.0556 0.0462 0.0545 0.0520 0.0521 0.0520 0.0521 0.0520 0.0575 0.0495 0.0575 0.0495 0.0523 0.0552 0.0555 0.0552 0.0555 0.0552 0.0555 0.
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A Sample C2C	Grain Grain Grain CM microtexture Grain	27 28 30 1 1 2 3 3 4 4 5 6 6 7 7 8 8 9 10 11 12 13 14 15 16 17 17 18 9 9 20 22 22	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.21 1.93 2.28 2.32 2.24 2.22 2.24 2.22 2.24 2.27 2.37	1624.996 1626.372 1626.728 1626.606 1.47 1.43 1.44 1.44 1.54 1.55 1.55 1.44 1.44 1.56 1.39 1.49 1.49 1.49 1.40 1.36 1.39 1.33 1.36 1.35 1.50	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.65920 0.6680 0.6683 0.6721 0.6782 0.6721 0.6683 0.6723 0.6723 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6883 0.66851 0.7065 0.6891 0.6891 0.6891 0.6891 0.6891 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6691 0.6682 0.6681 0.6682 0.6683 0.6682 0.6683 0.6682 0.6683	29,949 28,779 26,921 26,251 A _D /A _G 3,22 3,00 3,32 3,27 3,38 3,40 3,17 3,04 3,04 3,04 3,04 3,04 3,04 3,04 3,04	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7176 0.7126 0.7126 0.7131 0.7131 0.7136 0.7131 0.7136 0.7138 0.7138 0.7131 0.7138 0.7131 0.7238 0.7112 0.7062 0.7745 0.7745 0.7745 0.7128	320.05 324.07 323.94 321.95 325.17 323.88 323.65 323.87 323.59 322.56 322.56 322.56 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.67 323.79	351.54 350.51 361.16 355.73 340.83 342.88 334.36 345.98 339.18 342.72 353.01 347.52 353.01 347.52 353.77 353.77 352.07 355.94 352.66 354.15 356.11 350.82 339.26	379.74 376.11 366.56 371.03 340.60 357.48 359.26 380.13 339.61 333.10 345.72 360.48 377.30 345.72 360.48 377.30 345.72 362.56 354.91 362.56 354.91 366.23 366.23	0.0531 0.0465 0.0480 0.0534 0.0610 0.0622 0.0522 0.0516 0.0687 0.0687 0.0687 0.0687 0.0687 0.0687 0.0648 0.0550 0.05516 0.05516 0.0426 0.0534 0.0534 0.0465 0.0465 0.0465 0.0465 0.0465 0.05519	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0520 0.0520 0.0520 0.0520 0.0523 0.0552 0.0553 0.0553 0.0553 0.0553 0.0553 0.0553 0.0553 0.0553 0.0553 0.0551 0.0551 0.0553 0.0551 0.0551 0.0553 0.0551 0.0551 0.0555 0.
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Eaclies Laminated black chert Laminated black chert	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain Grain CM microtexture Grain	27 28 30 30 1 1 2 2 3 3 4 4 5 6 6 7 7 8 9 9 10 0 11 12 13 14 4 5 6 6 7 7 8 8 9 9 10 0 11 2 2 3 12 2 9 2 9 2 9 2 9 2 9 30 2 30 30 30 30 30 30 30 30 30 30 30 30 30	130883.813 93238.443 74990.048 77585.568 R 1 2.18 2.10 2.47 2.21 2.21 2.21 2.21 2.21 2.25 2.21 1.93 2.28 2.32 2.24 2.22 2.24 2.27 2.27 2.27 2.27 2.2	1624.996 1626.372 1626.728 1626.606 F D1/C 1.47 1.43 1.44 1.41 1.54 1.55 1.55 1.44 1.44 1.44	2878.699 2131.664 2131.664 2131.664 0.6926 0.6860 0.6771 0.7118 0.6980 0.6680 0.6683 0.6721 0.6683 0.6721 0.6783 0.6721 0.6783 0.6725 0.6883 0.6785 0.6685 0.6685 0.6685 0.6685 0.6685 0.6685 0.6685 0.6694 0.6685 0.6684 0.6685 0.6684 0.6685 0	29,949 28,779 26,921 26,921 26,251 3,22 3,00 3,32 3,27 3,38 3,40 3,37 3,34 3,36 3,37 3,37 3,38 3,29 3,349 3,379 3,379 3,379 3,70 3,70 3,70 3,70 3,70 3,70 3,70 3,70	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7136 0.7061 0.6984 0.7133 0.77145 0.7062 0.7745 0.77286 0.7745 0.77286 0.7745 0.77286 0.7745 0.77286 0.7745 0.77286 0.7745 0.77286 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7745 0.7728 0.7715 0.7745 0.6844	320.05 324.07 323.94 321.95 325.17 321.69 323.85 323.85 323.85 323.85 323.85 322.56 326.79 330.21 322.56 330.21 322.56 330.21 322.56 330.21 322.57 330.21 322.57 330.21 322.57 330.21 322.57 330.21 322.57 325.57 35.57 35.57 35.57 35.57 35.57 35.57 35.57 35.57 35.57 35.57 35.57	351.54 350.51 350.51 355.73 340.83 342.88 334.38 345.98 339.18 345.98 339.18 345.98 339.18 345.98 339.18 345.98 339.18 345.98 353.01 347.52 353.01 354.15 355.04 355.04 355.04 355.04 355.04 314.72	379.74 376.11 366.56 371.03 357.48 359.26 380.13 339.61 353.10 353.10 353.10 360.48 377.30 362.48 377.30 362.48 377.30 362.48 377.50 378.56 354.82 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.23 366.24 366.24 366.25 353.83 365.58	0.0531 0.0465 0.0480 0.0534 0.0650 0.0620 0.0620 0.0516 0.0516 0.0516 0.0567 0.05687 0.05687 0.05687 0.05687 0.05687 0.0550 0.0550 0.0550 0.0550 0.0550 0.0553 0.0465 0.0553 0.0465 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.0554 0.05550 0.05550 0.05550 0.05550 0.055500000000	0.0562 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0522 0.0522 0.0522 0.0522 0.0525 0.0525 0.0525 0.0555 0.0495 0.0555 0.00555 0.007555 0.007555 0.00755 0.007550 0.007555 0.007555 0.00755
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A Sample C2C	Grain Grain	27 28 29 30 1 2 2 3 3 4 5 5 6 6 7 7 8 8 9 9 10 11 11 12 2 3 3 4 4 5 5 6 6 7 7 7 8 9 9 10 10 11 11 2 2 3 3 4 4 5 5 6 6 7 7 7 7 8 8 9 9 9 9 10 10 10 10 10 10 10 10 10 10 10 10 10	130883.813 93238.443 774990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.21 1.93 2.22 2.24 2.22 2.24 2.22 2.24 2.22 2.24 2.22 2.24 2.27 2.37 2.05 2.21 1.70	$\begin{array}{c} 1624.996\\ 1626.372\\ 1626.728\\ 1626.606\\ \hline\\ \hline\\$	2878.699 2131.664 1817.172 1925.822 0.6880 0.6771 0.7118 0.6880 0.6880 0.6683 0.6721 0.6788 0.6723 0.6723 0.6723 0.6723 0.6788 0.6788 0.6683 0.6683 0.6685 0	29,949 28,779 26,921 26,221 26,251 A₀/A₆ 3,22 3,300 3,32 3,27 3,340 3,340 3,340 3,340 3,340 3,349 3,0493,049 3,049 3,049 3,049 3,0493,049 3,049 3,049 3,049 3,049 3,0493,049 3,049 3,049 3,0493,049 3,049 3,049 3,049 3,049 3,049 3,049 3,049 3,0493,049 3,049 3,049 3,049 3,049 3,049 3,049 3,049 3,0493,049 3,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,049 3,0493,049 3,0493,049 3,0493,04	0.7212 0.7122 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7134 0.7134 0.7134 0.7135 0.7135 0.7135 0.7135 0.7131 0.7128 0.7131 0.7128 0.7112 0.7726 0.77145 0.77145 0.7128 0.7128	320.05 324.07 323.94 321.95 325.17 321.69 323.85 323.85 323.85 323.85 323.85 322.56 322.56 322.56 322.56 322.56 322.56 323.67 330.21 323.67 330.21 324.53 326.73 318.91 326.73 326.73 326.73 327.9 326.73 327.9 326.79	351.54 350.51 361.16 355.73 340.88 342.88 344.88 344.88 344.78 345.98 334.78 345.98 334.78 345.98 334.72 353.07 355.94 352.66 355.94 352.66 355.61 356.81 350.82 359.26 351.11 350.82	379.74 376.11 366.56 371.03 340.60 357.48 359.26 339.61 339.61 339.61 3353.10 345.72 360.48 377.30 345.72 360.48 377.30 345.56 354.91 364.44 377.60 378.56 354.81 364.23 366.23 366.23 366.23	0.0531 0.0485 0.0485 0.0534 0.0534 0.0610 0.0620 0.0620 0.0622 0.0512 0.0647 0.0648 0.0550 0.0648 0.05516 0.05354 0.05556 0.055666 0.0556666 0.0556666666666	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0520 0.0521 0.0521 0.0521 0.0552 0.0495 0.0554 0.0554 0.0554 0.0554 0.0552 0.0553 0.0553 0.05517 0.0558 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0555 0.0555 0.0556 0.0555 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0557 0.0556 0.0556 0.0557 0.0556 0.05570000000000
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Eaclies Laminated black chert Laminated black chert	D4A D4A D4A D4A D4A C2C C2C	Grain Grain Grain CM microtexture Grain Gr	27 28 30 30 1 1 2 2 3 3 4 4 5 6 6 7 7 8 9 9 10 0 11 12 13 14 4 5 6 6 7 7 8 8 9 9 10 0 11 2 2 3 12 2 9 2 9 2 9 2 9 2 9 30 2 30 30 30 30 30 30 30 30 30 30 30 30 30	130883.813 74990.048 77585.568 R 1 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.25 2.21 1.93 2.28 2.32 2.24 2.22 2.24 2.27 2.22 2.24 2.27 2.22 2.24 2.27 2.22 2.24 2.27 2.22 2.24 2.27 2.22 2.24 2.27 2.22 2.24 2.27 2.27	1624.996 1626.728 1626.728 1626.606 1.47 1.43 1.44 1.44 1.54 1.55 1.55 1.44 1.44 1.55 1.55	2878.699 2131.664 2131.664 2131.664 0.6860 0.6771 0.7118 0.6880 0.66920 0.6883 0.6721 0.6782 0.6721 0.6883 0.6721 0.6783 0.6721 0.6883 0.6783 0.6783 0.6783 0.6783 0.6783 0.6895 0.6895 0.6895 0.6895 0.6895 0.6895 0.6895 0.6895 0.6694 0.6681 0.6297 0.6881 0.6297 0.6881 0.6297 0.6885 0.6297 0.6297 0.6885 0.6297 0.6885 0.6297 0.629	29,949 28,779 26,921 26,251 A ₀ /A ₆ 3.00 3.32 3.27 3.38 3.40 3.74 3.34 3.34 3.34 3.34 3.34 3.34 3.34	0.7212 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7134 0.7133 0.7156 0.7061 0.6984 0.7113 0.7728 0.77062 0.77266 0.77278 0.77278 0.77278 0.77128 0.77278 0.7726 0.77278 0.77278 0.77278 0.77278 0.77266 0.77266 0.77278 0.77266 0.77278 0.7726 0.77266 0.77278 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77278 0.77067 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.77278 0.7726 0.7728 0.77	320.05 324.07 323.94 323.94 321.95 325.17 321.69 323.85 323.87 323.87 323.87 323.86 323.87 324.67 330.21 323.67 330.21 323.67 330.21 323.67 330.21 323.67 323.67 323.67 323.67 323.63 323.63 323.63 336.58 333.80 ΔT C* (2)	351.54 350.51 361.16 355.73 340.83 342.88 342.81 344.83 347.52 353.01 342.72 353.01 347.52 353.01 352.66 354.15 352.66 354.15 355.04 352.66 354.15 355.04 352.66 354.15 355.04 352.66 354.15 355.27 355.04 352.66 354.15 355.27 355.27 355.27 355.27 355.41 356.11 314.72 25.08 47 C* (3)	379.74 376.11 366.56 371.03 350.26 357.48 359.26 380.13 359.26 380.13 339.61 355.26 339.61 355.26 339.61 333.61 333.61 333.61 3345.72 365.95 354.82 366.23 366.23 366.23 366.23 366.23 354.82 366.23 354.82 366.23 354.82 355.85 355.85 375.05	0.0531 0.0465 0.0480 0.0534 0.06524 0.0620 0.0524 0.0524 0.0526 0.0526 0.0526 0.0526 0.0516 0.0648 0.0476 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0534 0.0555 0.0516 0.0558 0.0542 0.05580 0.05580 0.05580000000000	0.0562 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0575 0.0588 0.0575 0.0588
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A Sample C2C C2C <	Grain Grab Grain G	27 28 29 30 1 2 3 3 1 2 3 4 5 6 6 7 8 9 9 10 11 12 13 14 15 16 17 18 19 20 21 22 33 4 4 5 6 6 7 7 8 9 9 10 10 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 12 2 11 11	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.10 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.12 2.21 2.21 2.25 2.25 2.25 2.25 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.31 2.27 2.32 2.27 2.37 2.41 1.53 1.41	1624.996 1626.372 1626.728 1626.606 147 147 143 144 141 158 158 155 155 155 155 155 155 155 15	2878.699 2131.664 1817.172 1925.822 0.6780 0.6880 0.6880 0.6887 0.6887 0.6788 0.6721 0.6778 0.6788 0.6721 0.6788 0.6887 0.6895 0.6953 0.6953 0.6953 0.6953 0.6953 0.6953 0.6953 0.6953 0.6981 0.6981 0.6981 0.6881 0.6297 0.6046 0.5889 0.622 0.6295 0.6291 0.6297 0.6046 0.5889 0.6297 0.6046 0.5889 0.6297 0.6046 0.5889 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.6046 0.5881 0.6297 0.7257 0.6297 0.7257 0.6297 0.6297 0.7257 0.6297 0.7257 0.6297 0.72577 0.72577 0.72577 0.72577 0.725777 0.7257777 0.7257	29,949 28,779 26,921 26,221 26,251 A_D/A_G 3,22 3,30 3,32 3,40 3,31 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,34 3,36 3,32 3,34 3,36 3,32 3,36 3,36 3,37 3,36 3,37 3,37 3,38 3,36 3,37 3,36 3,37 3,37 3,37 3,38 3,39 3,30 3,59 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,09 3,40 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,43 3,45 3	0.7212 0.7125 0.7125 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7134 0.7134 0.7135 0.7135 0.7135 0.7135 0.7135 0.7135 0.7131 0.7131 0.7131 0.7131 0.7125 0.7065 0.7145 0.7065 0.6841 0.6903 0.7232	320.05 324.07 324.07 324.34 321.95 321.95 321.85 321.85 321.87 321.87 321.87 323.89 323.89 323.89 323.87 323.89 323.67 323.67 323.67 323.67 324.67.3 318.91 317.66 323.06 323.65 333.80 ΔT C* (2) 333.80	351.54 350.51 360.51 360.51 355.73 355.73 355.73 347.15 347.15 347.15 347.15 355.73 352.07 352.07 352.07 352.07 352.07 352.07 352.66 354.15 350.42 351.11 351.5.04 314.72 295.08 ΔTC*(3) 357.20	379.74 376.11 366.56 371.03 357.48 359.26 380.13 359.26 380.13 359.26 380.13 359.26 359.26 359.26 359.26 359.27 360.48 377.30 362.56 354.91 362.56 354.91 362.56 354.91 364.44 377.60 378.56 364.44 377.60 355.81 354.82 366.23 366.23 366.25 354.83 366.25 354.83 366.25 354.83 366.25 354.83 366.25 354.83 366.25 355.88 375.05 17 C° (4)	0.0531 0.0465 0.0460 0.0534 0.0534 0.0524 0.0624 0.0525 0.0525 0.0525 0.05516 0.0664 0.0654 0.0654 0.05516 0.0664 0.0654 0.0664 0.0654 0.0664 0.0654 0.06550 0.0645 0.0550 0.0550 0.0550 0.0555	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0495 0.0554 0.0554 0.0554 0.0554 0.0554 0.0552 0.0554 0.0555 0.0558 0.0555 0.0558 0.0558 0.0558 0.0558 0.0558 0.0558 0.0588 0.0558 0.0588 0.0575 0.06884 0.0544 0.05884 0.0576 0.05884 0.0576 0.06884 0.0576 0.0576 0.0576 0.0576 0.0577 0.0578 0.0577 0.0578 0.0577 0.0705 0.
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grab Grain G	27 28 29 30 1 2 3 3 4 5 5 6 6 7 7 8 9 9 100 11 12 2 13 14 15 16 7 7 8 9 9 100 11 12 2 3 3 2 4 25 23 24 25 29 30 20 20 20 20 20 20 20 20 20 20 20 20 20	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.10 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.11 2.12 2.21 2.21 2.23 2.25 2.25 2.25 2.25 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.27 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.37 2.37 2.37 3.37	1626.992 1626.992 1626.728 1626.606 147 147 143 144 141 158 155 155 155 155 155 155 15	2878.699 2131.664 1817.172 1925.822 0.6786 0.6880 0.6880 0.6887 0.6788 0.6788 0.6787 0.6778 0.6788 0.7705 0.6778 0.6788 0.7005 0.6953 0.6953 0.6953 0.6953 0.6953 0.6953 0.6981 0.6981 0.6981 0.6981 0.6981 0.6981 0.6297 0.6046 0.5889 0.6725 0.6765 0.6765 0.7035 0.6765 0.6788 0.6788 0.7067 0.6985 0.7055 0.6985 0.7055	29.949 26.921 26.221 26.251 3.22 3.32 3.32 3.32 3.32 3.40 3.04 3.04 3.04 3.04 3.04 3.04 3.04	0.7212 0.7125 0.7125 0.7175 0.7175 0.7175 0.7175 0.7175 0.7181 0.7131 0.7134 0.7134 0.7135 0.7135 0.7135 0.7135 0.7135 0.7135 0.7135 0.7131 0.7238 0.7112 0.7062 0.7145 0.7062 0.7145 0.7062 0.7145 0.6841 0.6903 0.7232 0.6907 0.7146	320.05 324.07 323.94 321.95 321.95 321.91 321.92 321.91 321.91 321.92 321.92 321.92 321.92 323.97 323.87 323.87 323.67 330.21 323.67 323.67 323.67 323.67 333.83 335.81 335.81 335.81 335.81 335.81 335.81 335.81 335.81 335.81 335.81 335.81 335.81 323.65	351.54 330.51 330.51 340.83 342.83 342.84 344.84 344.84 347.75 355.77 355.77 355.94 352.65 354.15 352.65 352.65 351.11 350.62 355.11.11 355.26 355.27 355.27 355.20 357.20 357.20 357.34	379.74 376.11 376.11 340.60 357.60 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 354.91 354.91 354.91 354.91 354.91 354.91 354.91 355.91 356.23 366.23 377.60 353.83 355.91 355.83 375.05 17 C° (4 363.81 363.81 363.81 363.81 363.81 353.81 353.81 355.81 375.05 354.82 355.81 375.05 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.83 375.95 355.95 355.83 375.95 355.9	0.0531 0.0465 0.0460 0.0534 0.0534 0.0524 0.0522 0.0526 0.0526 0.0516 0.0564 0.0516 0.0664 0.0654 0.0654 0.0516 0.0664 0.0654 0.0664 0.0664 0.0654 0.0650 0.0650 0.0550 0.0550 0.0550 0.05519 0.0953 0.0953 0.0953 0.0953 0.0953 0.0953 0.0953 0.0953 0.0550	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0520 0.0521 0.0521 0.0552 0.0495 0.0495 0.0495 0.0552 0.0552 0.0552 0.0552 0.0558 0.0557 0.0558 0.0525 0.0558 0.0525 0.0558 0.0525 0.0583 0.0525 0.0583 0.0525 0.0583 0.0525 0.06884
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Laminated black chert Laminated black chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grab Grain G	27 28 29 30 1 2 2 3 3 4 5 5 6 6 7 7 8 9 9 10 11 12 2 1 3 3 4 4 5 5	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.10 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.27 2.37 2.29 2.27 2.37 2.28 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.38	1624.996 1626.728 1626.728 1626.606 Гр <u>1/6</u> 1.47 1.43 1.34 1.34 1.58 1.55 1.55 1.54 1.58 1.59 1.44 1.49 1.49 1.49 1.49 1.49 1.49 1.4	2878.699 2131.664 1817.172 1925.822 1917.172 1925.822 1917.172 1925.822 1917.172 1927.172 0.6880 0.6771 0.7118 0.6782 0.6782 0.6782 0.6782 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67852 0.67652 0.7065 0.67852 0.6774 0.6881 0.6774 0.6297 0.6297 0.6294 0.6297 0.6294 0.6274 0.6274 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.6297 0.67760 0.7735 0.7735 0.6351 0.7735 0.6351 0.7735 0.6351 0.7735 0.6351 0.6351 0.7735 0.6354 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.6354 0.7735 0.6354 0.7735 0.6354 0.7735 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.6354 0.7735 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.6354 0.7735 0.6354 0.	29,949 28,779 26,921 26,251 26,251 26,251 3,00 3,22 3,30 3,27 3,340 3,340 3,347 3,344 3,364 3,376 3,349 3,309 3,29 3,376 3,09 3,07 3,07 3,07 3,07 3,09 3,07 3,07 3,07 3,07 3,07 3,07 3,07 3,07 3,07 3,09 3,07 3,07 3,07 3,07 3,07 3,07 3,07 3,09 3,07 3,0	0.7212 0.7122 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7181 0.7181 0.7183 0.7183 0.7184 0.7183 0.7184 0.7183 0.7184 0.7183 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7185 0.7065 0.7145 0.7065 0.6841 0.6903 R₂ (1) 0.7282 0.7014 0.7021 0.7014 0.70714 0.7076	320.05 324.05 324.05 324.34 321.35 321.35 323.34 321.35 323.87 333.80 ΔT C (2) 319.17 333.63 323.61 324.53 326.17	351.54 330.51 330.51 331.54 335.72 335.72 337.82 339.82 342.82 339.18 342.72 353.01 342.72 353.01 347.52 352.65 352.65 352.65 352.61 352.61 352.61 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.70 357.34 354.91 354.91	379.74 376.11 376.11 376.02 340.460 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 354.57 365.91 354.92 356.29 355.88 3	0.0531 0.0465 0.0460 0.0534 0.0534 0.0524 0.0526 0.0526 0.0526 0.0526 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0519 0.0533 0.0467 0.0519 0.0531 0.0531 0.0531 0.0531 0.0550	0.0562 0.0551 0.0596 0.0462 0.0545 0.0520 0.0520 0.0520 0.0521 0.0521 0.0521 0.0523 0.0523 0.0523 0.0523 0.0523 0.0552 0.0552 0.0552 0.0552 0.0552
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A D4A D4A D4A D4A C2C C2C	Grain Grain	27 28 29 30 1 22 3 30 1 2 2 3 4 4 5 6 6 7 7 8 9 9 10 11 12 2 3 3 4 4 5 5 6 6 17 1 22 23 24 17 12 2 9 30 1 2 2 9 30 1 2 2 9 30 1 2 3 3 30 2 9 2 9 30 2 9 2 9 30 2 9 2 9 30 2 9 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 2 9 30 30 1 1 2 2 3 3 3 4 5 6 6 6 7 7 7 8 8 9 9 10 11 11 12 2 3 3 3 1 3 1 11 11 12 2 3 3 3 1 3 1	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.10 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.27 2.37 2.29 2.27 2.37 2.28 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.37 2.38	1624.996 1626.972 1626.728 1626.606 1.47 1.43 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6980 0.66980 0.66980 0.66980 0.66980 0.6721 0.6721 0.66980 0.66985 0.6728 0.6728 0.67885 0.67885 0.66985 0.66985 0.66985 0.66985 0.66891 0.66891 0.66891 0.66891 0.66891 0.66891 0.66891 0.66891 0.66891 0.66891 0.66895 0.66852 0.66854 0.67724 0.66859 0.67724 0.66881 0.66891 0.7724 0.66891 0.66891 0.66891 0.66891 0.66891 0.7724 0.66891 0.66891 0.66891 0.7724 0.66891 0.66891 0.7724 0.66891 0.6773 0.66954 0.7735 0.7755 0.7755 0.7755 0.7755 0.7755 0.77	29,949 28,779 26,921 26,251 26,251 26,251 3,02 3,02 3,02 3,02 3,27 3,38 3,40 3,37 3,04 3,34 3,55 3,57 3	0.7212 0.7122 0.7125 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7133 0.7134 0.7133 0.7136 0.7061 0.6984 0.7131 0.7238 0.7062 0.77662 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.7727 0.77128 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.7727 0.77266 0.77266 0.77266 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.7726 0.7727 0.7726 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.77266 0.7727 0.7726 0.7727 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.7726 0.7727 0.77726 0.7726 0.77726 0.77726 0.77727 0.77726 0.77726 0.77727 0.77726 0.77727 0.77727 0.77726 0.77727 0.77767 0.77727 0.77767	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 321.87 321.87 323.89 323.87 323.87 323.87 323.87 323.87 323.67 323.67 323.67 323.67 323.67 323.67 333.83 333.80 333.80 323.20 323.20 323.20 323.20 333.80 333.80 328.67 328.67 328.61 326.51 326.51 326.51	351.54 350.51 360.51 360.51 355.73 365.71 364.98 347.15 347.15 347.15 347.15 347.15 347.15 357.73 352.07 352.66 354.15 355.94 352.66 354.15 355.94 350.82 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.95 357.70 355.734 355.84.91 355.94.91 359.98	379.74 376.11 366.56 371.03 377.03 377.03 357.48 359.26 357.43 339.61 357.43 339.61 355.10 345.72 356.14 377.30 345.73 360.43 376.256 366.43 376.591 377.60 377.60 377.65 377.55 353.83 366.73 353.83 353.83 353.83 355.35 377.55 377.85 377.	0.0531 0.0465 0.0480 0.0534 0.0610 0.0524 0.0620 0.0524 0.0526 0.0526 0.0526 0.0562 0.0562 0.0562 0.0562 0.0566 0.0667 0.06648 0.0476 0.05516 0.0476 0.05516 0.0455 0.05516 0.0553 0.0553 0.0553 0.05531 0.05551 0.0465 0.05550 0.05551 0.0465 0.05551 0.05551 0.05521 0.05550 0.05520 0.05520 0.05520 0.05520 0.05520 0.05550 0.05520 0.055500 0.055500 0.055500 0.055500 0.055500 0.055500 0.055500 0.055500000000	0.0562 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0575 0.0523 0.0525 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A D4A D4A D4A D4A C2C C2C	Grain Grain Grain CM microtexture Grain Gr	27 28 29 30 1 1 2 3 3 4 4 5 5 6 6 7 7 8 9 9 10 0 11 11 12 13 3 4 4 15 12 23 24 24 25 23 24 25 23 24 11 12 13 14 15 15 6 6 7 8 9 9 10 10 10 10 10 10 10 10 10 10 10 10 10	130883.813 74990.048 77585.568 R 1 2.18 2.10 2.47 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.2	1624.996 1626.728 1626.728 1626.606 Γ <u>D1/C</u> 1.47 1.43 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44 1.44 1.56 1.59 1.49 1.38 1.39 1.34 1.31 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.33 1.33 1.33 1.34 1.33 1.33 1.33 1.34 1.33 1.33 1.34 1.33 1.33 1.34 1.33 1.34 1.33 1.33 1.34 1.33 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.34 1.34 1.33 1.34 1.34 1.34 1.33 1.34 1.34 1.34 1.33 1.34	2878.699 2131.664 1817.172 1925.822 1917.172 1925.822 0.6860 0.6771 0.7118 0.6980 0.66880 0.66980 0.66880 0.66980 0.66980 0.6721 0.66980 0.6721 0.66980 0.6721 0.68910 0.66985 0.7005 0.66985 0.7005 0.68910 0.7035 0.6297 0.66891 0.6297 0.66891 0.6297 0.66891 0.6297 0.66891 0.6297 0.66891 0.6297 0.6685 0.66954 0.7724 0.6735 0.6735 0.7735 0.7735 0.7735 0.7735 0.7735 0.67319 0.7712 0.66919 0.77112 0.66919 0.7712 0.66919 0.7712 0.66919 0.7712 0.66919 0.66919 0.7712 0.66919 0.7712 0.66919 0.6771 0.66919 0.7712 0.7712 0.771	29,949 28,779 26,921 26,921 26,251 A₀/A₆ 3.22 3.30 3.32 3.40 3.74 3.44 3.74 3.64 3.74 3.64 3.74 3.64 3.62 3	0.7212 0.7122 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7133 0.7134 0.7133 0.7156 0.7061 0.6984 0.7131 0.7238 0.7766 0.7766 0.7766 0.7766 0.7727 0.7727 0.7727 0.7775 0.7727 0.7728 0.7727 0.7727 0.7727 0.7727 0.7728 0.7727 0.7727 0.7728 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.77726 0.7726 0.7726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77767 0.77767 0.77767 0.77766 0.77766 0.77767 0.77766 0.77766 0.77766 0.77767 0.77766 0.77066 0.7708 0.77	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 323.89 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.67 323.67 323.67 323.67 323.67 333.83 333.80 324.57 326.51 323.62 333.80 333.80 324.67 333.80 328.57 326.51 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 3228.57 324.69 324.69	351.54 350.51 360.51 360.51 350.51 355.73 364.59 347.15 347.15 347.15 347.15 347.15 347.15 355.94 352.07 352.07 352.07 352.07 355.94 352.66 354.15 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.95 355.96 357.20 355.96 357.34 355.95 354.91 355.92 355.93 358.97 358.97 358.97 358.97 358.97 3	379.74 376.11 366.56 371.03 371.03 377.03 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 355.10 345.72 355.10 345.72 356.48 377.30 362.56 356.48 377.50	0.0531 0.0465 0.0480 0.0534 0.0610 0.0524 0.0620 0.0524 0.0526 0.0526 0.0526 0.0526 0.0562 0.05516 0.06648 0.0476 0.05516 0.05516 0.05516 0.05516 0.0495 0.05516 0.05516 0.05534 0.05534 0.05534 0.05534 0.05534 0.05534 0.05534 0.05534 0.05550 0.05551 0.04642	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0520 0.0522 0.0527 0.0527 0.0527 0.0525 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain Grain CM microtexture Grain Gr	27 28 29 30 1 1 2 3 3 4 4 5 5 6 6 7 7 8 8 9 100 11 12 13 14 15 7 7 8 9 9 10 11 12 13 3 4 4 5 5 7 7 7 8 9 9 10 11 12 13 3 4 4 5 5 7 7 7 7 8 9 9 10 10 10 10 10 10 10 10 10 10 10 10 10	130883.813 74990.048 77585.568 R 1 2.18 2.10 2.47 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.2	1624.996 1626.372 1626.728 1626.606 Γ <u>D1/C</u> 1.43 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44 1.44 1.56 1.55 1.44 1.45 1.56 1.50 1.50 1.46 1.50 1.50 1.45 1.50 1.46 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.50 1.44 1.50 1.33 1.50 1.43 1.33 1.36 1.33 1.36 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.34 1.33 1.36 1.33 1.34 1.33 1.34 1.33 1.36 1.33 1.34 1.33 1.36 1.33 1.34 1.33 1.36 1.33 1.34 1.33 1.36 1.33 1.34 1.33 1.36 1.34 1.33 1.36 1.33 1.36 1.34 1.33 1.36 1.34 1.33 1.36 1.34 1.33 1.36 1.34 1.35 1.36 1.34 1.35 1.36 1.34 1.33 1.36 1.34 1.35 1.36 1.34 1.35 1.36 1.34 1.36 1.36 1.36 1.36 1.36 1.34 1.36	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6880 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.6680 0.7005 0.7005 0.7005 0.6680 0.7005 0.6855 0.7005 0.7005 0.7005 0.7005 0.6855 0.7005 0.7005 0.7005 0.7005 0.6855 0.7005 0.7005 0.7005 0.7005 0.6855 0.7005	29,949 28,779 26,921 26,921 26,251 A₀/A₆ 3.22 3.30 3.27 3.34 3.40 3.74 3.04 3.74 3.04 3.74 3.04 3.74 3.04 3.74 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.04 3.05 2.57 A₀/A₆ A ₀ /A ₆ A ₀ /A ₁ /A ₁ A ₀ /A ₁ /A ₁ A	0.7212 0.7122 0.7125 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7133 0.7134 0.7133 0.7136 0.7061 0.6984 0.7131 0.7238 0.7062 0.77662 0.77662 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.7727 0.77266 0.7726 0.7726 0.77266 0.7727 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.7727 0.7726 0.77726 0.77726 0.7706 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77727 0.77767 0.77777 0.77767 0.7777777777	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 321.87 321.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 324.57 323.67 333.83 333.80 328.57 326.11 328.57 326.51 322.51 322.52 323.62 333.83 328.57 326.51 322.55 322.55 322.55 322.55 322.55 322.55 322.55 322.55 322.55 323.75	351.54 350.51 360.51 360.51 355.73 365.73 364.98 347.15 347.15 347.15 347.15 347.15 347.15 357.73 352.07 352.66 354.15 355.94 352.66 354.15 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.95 355.96 357.09 355.96 355.97 355.98 355.98 355.98 355.98 355.98 355.98 355.98 355.98 355.98 3	379.74 376.11 366.56 371.03 371.03 377.03 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 357.48 357.48 355.10 348.01 355.10 348.01 355.10 366.43 377.50 377.50 377.50 377.50 378.56 375.48 376.25 375.48 376.25 376.25 377.27 371.28 376.25 377.27 377.27 377.07 377.07 375.48 360.36 377.27 377.27 375.48 377.27 377.07 375.48 377.27 375.48 377.27 377.07 375.28 377.27 377.27 375.28 377.27 375.28 377.27 375.28 377.27 377.27 377.27 375.28 377.27 375.28 377.27 377.27 375.28 377.27 375.28 377.27 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 377.27 375.28 375.28 377.29 377.29 377.29 377.27 375.29 377.29	0.0531 0.0465 0.0480 0.0534 0.0610 0.0534 0.0624 0.0524 0.0526 0.0526 0.0526 0.0526 0.0526 0.0516 0.0667 0.06648 0.0476 0.0516 0.0516 0.0516 0.0516 0.0516 0.0516 0.0534 0.05516 0.0534 0.05516 0.05534 0.05516 0.0550 0.05510 0.0550 0.0551 0.0465 0.0550 0.05511 0.0465 0.0550 0.05511 0.0465 0.0550 0.05511 0.0465 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.0550 0.05511 0.05551 0.05511 0.05551 0.05511 0.05557 0.05551 0.05557 0.05551 0.05557 0.05577 0.05577 0.05577 0.05577 0.055770000000000	0.0562 0.0551 0.0596 0.0462 0.0545 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0523 0.0575 0.0575 0.0575 0.0523 0.0523 0.0525 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain	27 28 29 30 1 1 2 3 3 4 5 6 7 7 7 8 9 9 10 11 12 3 3 4 4 5 6 7 7 7 7 8 9 9 10 11 12 22 23 24 25 24 25 24 25 24 25 24 25 26 26 26 26 26 26 26 26 26 26 26 26 26	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.17 2.27 2.37 2.27 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.27 2.37 2.28 2.47 2.28 2.47 2.25 2.27 2.27 2.28 2.47 2.27 2.28 2.47 2.27 2.28 2.47 2.27 2.27 2.28 2.47 2.27 2.27 2.28 2.47 2.27 2.27 2.28 2.47 2.27 2.27 2.28 2.47 2.27 2.27 2.28 2.27 2.27 2.28 2.27 2.28 2.27 2.27 2.28 2.27 2.27 2.28 2.27 2.27 2.28 2.27 2.27 2.28 2.27 2.27 2.28 2.27 2.27 2.27 2.28 2.27 2.27 2.27 2.28 2.21 2.31	1626.972 1626.972 1626.728 1626.606 147 147 143 144 141 158 155 155 155 155 155 155 15	2878.699 2131.664 1817.172 1925.822 0.6680 0.6680 0.6680 0.66837 0.6680 0.66837 0.6721 0.6778 0.6721 0.6788 0.6721 0.6788 0.6721 0.6788 0.6725 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6691 0.6691 0.6691 0.6691 0.6691 0.6297 0.6695 0.7705 0.6720 0.6721 0.6724 0.6681 0.6297 0.6646 0.5859 0.7725 0.6695 0.7735 0.6695 0.7735 0.6695 0.7735 0.6695 0.7735 0.6695 0.7735 0.6695 0.7735 0.6735 0.6735 0.6735 0.7735 0.6756 0.7735 0.6757 0.6695 0.7735 0.6757 0.6695 0.7735 0.6757 0.6695 0.7735 0.6757 0.6757 0.6695 0.7735 0.6757 0.6757 0.6757 0.6757 0.6757 0.6757 0.7735 0.6757 0.7735 0.6757 0.6757 0.6757 0.6757 0.7735 0.6757 0.7735 0.6757 0.6757 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.6757 0.7735 0.77570 0.77570 0.77570 0.77570 0.775700 0.775700 0.77570000000000	29,949 26,921 26,221 26,251 3,22 3,32 3,32 3,32 3,32 3,32 3,32 3,3	0.7212 0.7122 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7181 0.7181 0.7181 0.7184 0.7183 0.7184 0.7183 0.71861 0.7181 0.71861 0.7181 0.71861 0.7182 0.7782 0.77782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.7782 0.77782 0.7782 0.777782 0.77780	320.05 324.05 324.05 324.05 321.65 321.65 321.65 321.65 321.65 321.65 321.65 321.65 321.65 323.87 323.87 322.86 322.86 323.87 323.87 323.87 323.67 323.87 323.86 323.86 323.87 323.87 330.21 323.87 323.87 323.86 324.53 323.63 323.63 333.83 333.83 333.83 333.83 328.57 328.57 328.57 328.57 328.57 328.57 328.57 328.57 328.57 328.57 3	351.54 330.51 330.51 331.16 335.27 342.87 342.87 344.38 347.35 347.35 347.35 347.35 347.35 347.35 347.35 347.35 352.65 354.15 352.65 354.15 352.65 354.15 352.65 351.11 350.62 357.41 355.02 357.41 355.02 357.41 355.03 357.20 357.43 355.03 357.43 358.87 358.87 358.87 355.00 358.87 358.87 355.01 357.93 355.07 355.07 358.87 355.01 3	379.74 376.11 366.56 377.03 376.13 376.13 377.03 353.26 335.26 336.27 3377.80 377.80 33	0.0531 0.0465 0.0460 0.0534 0.0554 0.0620 0.0624 0.0624 0.0624 0.06524 0.06576 0.06576 0.06676 0.06676 0.06676 0.06676 0.06676 0.06576 0.06579 0.06648 0.05519 0.06649 0.05519 0.06547 0.06547 0.05508 0.05508 0.05508	0.0502 0.0551 0.0596 0.0462 0.0545 0.0520 0.0520 0.0520 0.0520 0.0520 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0525 0.0552 0.0552 0.0552 0.0552 0.0552 0.0555 0.0557 0.0505 0.0502 0.0502 0.0502 0.0502 0.0502 0.0505 0.0555 0.
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain	27 28 29 30 1 1 2 3 3 4 5 6 7 7 7 8 9 10 11 12 3 3 4 5 6 7 7 7 7 8 9 9 10 11 12 20 23 24 25 24 25 24 25 24 25 24 25 24 11 12 13 3 4 11 12 13 13 14 14 15 16 16 17 17 17 18 18 19 10 11 11 12 11 13 11 14 11 15 11 10 11 11 11 11 11 11 11 11 11 11 11	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.22 2.27 2.28 2.28 2.28 2.24 2.31 2.28 2.40	1626.992 1626.992 1626.728 1626.606 147 143 143 144 141 158 155 155 156 146 147 144 144 144 144 144 144 144	2878.699 2131.664 1817.172 1925.822 0.6685 0.6685 0.6685 0.6685 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.7025 0.6695 0.7035 0.6695 0.7025 0.7025 0.6695 0.7025 0.7025 0.6695 0.7025 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.7055 0.70555 0.70555 0.7055 0.7055 0.7055 0.70555 0.7	29,949 26,921 26,221 26,251 26,251 3,22 3,32 3,32 3,32 3,32 3,32 3,32 3,3	0.7212 0.7122 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7175 0.7181 0.7181 0.7184 0.7183 0.7184 0.7183 0.7184 0.7183 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7184 0.7185 0.7065 0.7065 0.7065 0.7065 0.7076 0.70780 0.70780 0.70788 0.7020	$\begin{array}{c} 320.05\\ 324.07\\ 323.94\\ 323.94\\ 323.94\\ 323.94\\ 325.17\\ 325.17\\ 325.17\\ 325.17\\ 325.17\\ 325.18\\ 325.17\\ 325.18\\ 325.17\\ 325.18\\ 325.18\\ 325.18\\ 325.18\\ 325.18\\ 325.18\\ 330.21\\$	351.54 330.51 330.51 330.51 331.54 340.83 342.88 334.28 339.18 342.28 339.38 342.27 353.01 342.72 353.01 347.52 355.594 355.64 355.64 355.61 355.61 355.77 355.64 355.74 355.77 355.94	379.74 376.11 376.11 340.60 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 359.26 354.91 354.91 354.91 354.91 354.91 354.91 354.91 354.91 356.25 355.98 377.30 377.30 377.30 377.07 356.91 356.25 377.20 377.07 356.91 356.25 377.20 356.25 377.20 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 356.25 357.25 35	0.0531 0.0465 0.0460 0.0534 0.0554 0.0624 0.0524 0.0524 0.0524 0.05516 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.06516 0.05516 0.05516 0.05516 0.05519 0.05529 0.05519 0.055100 0.055100 0.05510000000000	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0520 0.0520 0.0520 0.0520 0.0520 0.0520 0.0525 0.04035 0.0525 0.0504 0.0552 0.0552 0.0552 0.0558 0.0557 0.0558 0.0557 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0556 0.0557 0.0558 0.0556 0.0557 0.0556 0.0556 0.0556 0.0556 0.0557 0.0556 0.0556 0.0556 0.0556 0.0557 0.0558 0.0556 0.0557 0.0556 0.0556 0.0556 0.0556 0.0557 0.0556 0.0556 0.0556 0.0556 0.0557 0.0556 0.0556 0.0556 0.0556 0.0556 0.0557 0.0556 0.0567 0.0556 0.0576 0.0576 0.0577 0.04776 0.0476 0.04776 0.0556 0.0556 0.0
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain Grain CM microtexture Grain Gr	27 28 29 30 1 2 3 3 4 4 5 5 6 7 7 8 9 9 9 10 11 12 23 24 25 21 17 18 19 10 11 2 11 2 13 14 15 16 6 7 7 8 8 9 9 10 11 2 13 14 14 5 15 16 16 17 17 17 18 17 18 19 19 10 10 10 10 10 10 10 10 10 10 10 10 10	130883.813 74990.048 77585.568 R 1 2.18 2.10 2.47 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.2	1624.996 1626.372 1626.728 1626.606 F D1/C 1.43 1.44 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 1817.172 1925.822 0.6860 0.6771 0.7118 0.6880 0.6680 0.6680 0.6680 0.6680 0.6680 0.6680 0.6721 0.6721 0.6721 0.6721 0.6891 0.6728 0.6728 0.6728 0.6728 0.6728 0.6728 0.6738 0.6728 0.6728 0.6891 0.6891 0.7035 0.7075 0.7035 0.7075	29,949 28,779 26,921 26,921 26,251 3,22 3,30 3,32 3,340 3,32 3,40 3,17 3,04 3,14 3,04 3,14 3,04 3,14 3,04 3,14 3,04 3,29 3,09 2,87 3,09 2,98 3,10 3,09 2,98 3,10 3,09 3,01 2,55 2,57 A A A A A A A A A A	0.7212 0.7122 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7156 0.7061 0.6984 0.7131 0.7238 0.7062 0.77662 0.77662 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.77266 0.7727 0.77062 0.77062 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7706 0.7707 0.7706 0.7707 0.7706 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7706 0.7726 0.7726 0.7726 0.7726 0.7727 0.77726 0.7726 0.7727 0.77726 0.7726 0.7727 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77727 0.77766 0.77726 0.77726 0.77726 0.77726 0.77727 0.77766 0.77727 0.77766 0.77727 0.77766 0.77727 0.77766 0.77767 0.77766 0.77766 0.77767 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77766 0.77728	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 321.87 321.87 321.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 324.57 323.67 333.83 333.80 328.57 326.51 323.62 333.80 333.80 328.57 322.51 322.51 322.51 322.51 322.51 322.51 322.51 322.51 322.52 322.51 322.51 322.51 322.51 322.51 322.51 322.51 322.51 322.52.31 <	351.54 350.51 360.51 360.51 355.73 365.73 364.98 347.15 347.15 347.15 347.15 347.15 347.15 357.73 352.07 352.66 354.15 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.94 355.95 355.95 355.98 355.96 355.96 355.96 355.96 355.96 355.96 355.96 355.96 355.96 355.98 355.98 3	379.74 376.11 366.56 371.03 377.03 377.03 357.48 359.26 335.48 359.26 335.49 355.49 355.40 355.10 345.72 356.41 377.50 354.84 377.50 366.45 31 366.45 31 364.44 377.60 377.50 364.44 377.60 377.50 364.44 377.50 364.44 377.50 364.44 377.50 364.44 377.50 364.44 377.50 364.44 377.50 364.44 377.50 364.44 377.50 366.75 355.81 377.50 366.75 377.50 377	0.0531 0.0465 0.0480 0.0534 0.0534 0.0650 0.0524 0.0524 0.0524 0.05516 0.0627 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0667 0.0550 0.0516 0.0776 0.0550 0.0516 0.0746 0.0555 0.0465 0.0555 0.0465 0.0555 0.0465 0.0555 0	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0526 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain Grain CM microtexture Grain Gr	27 28 29 30 1 1 2 3 3 4 4 5 6 6 6 7 7 8 9 9 10 112 13 4 4 5 6 6 7 7 8 9 9 10 112 12 13 4 4 5 6 6 6 7 7 7 8 9 9 9 10 11 12 12 3 3 4 4 4 4 5 6 6 6 6 6 6 7 7 7 9 9 9 10 11 12 12 14 14 14 15 16 16 10 10 10 11 12 12 10 10 10 10 10 10 10 10 10 10 10 10 10	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21 2.16 2.05 2.11 2.31 2.26 2.21 1.33 2.27 2.28 2.32 2.41 2.22 2.24 2.27 2.37 2.05 2.21 1.70 1.53 1.41 R ₁ 2.48 2.09 2.37 2.28 2.47 2.27 2.37 2.21 1.70 1.53 1.41 R ₁ 2.48 2.09 2.37 2.28 2.47 2.27 2.37 2.28 2.44 2.44 2.44 2.48 2.09 2.37 2.28 2.47 2.27 2.37 2.28 2.47 2.27 2.37 2.21 1.70 1.53 1.41 R ₁ 2.48 2.09 2.37 2.28 2.47 2.28 2.47 2.27 2.37 2.28 2.47 2.27 2.37 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.47 2.28 2.44 2.48 2.49 2.44 2.48 2.49 2.44 2.48 2.49 2.44 2.48 2.49 2.44 2.48 2.44 2.48 2.44 2.48 2.44 2.48 2.44 2.48 2.44 2.48 2.44 2.12	1624.996 1626.372 1626.728 1626.606 143 1.43 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 1817.172 1925.822 0.6860 0.6880 0.66771 0.7118 0.6880 0.66880 0.66880 0.66782 0.6721 0.6782 0.6721 0.6782 0.6721 0.6880 0.6721 0.6880 0.6782 0.6782 0.6782 0.6782 0.6782 0.6782 0.6782 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6695 0.67724 0.6891 0.6695 0.67724 0.6891 0.6695 0.6695 0.7035 0.7035 0.7035 0.7035 0.7035 0.7035 0.6797 0.6891 0.6891 0.6733 0.67724 0.6735 0.7035 0.7035 0.7035 0.7035 0.7035 0.7075 0.6895 0.7075 0.6895 0.7075 0.6895 0.7075 0.6895 0.7075 0.6975	29,949 28,779 26,921 26,921 26,251 3,22 3,30 3,22 3,340 3,27 3,34 3,40 3,37 4,50 3,50 3,57 3,57 3,57 3,57 3,57 3,57 3,57 3,57	0.7212 0.7122 0.7125 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7156 0.7061 0.6984 0.7131 0.7238 0.7062 0.7062 0.77662 0.77266 0.7727 0.7067 0.77067 0.77067 0.77080 0.7718 0.7718 0.7708 0.7718 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.7718 0.7718 0.77080 0.7718 0.7718 0.77080 0.7718 0.7718 0.7718 0.77080 0.7718	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 321.87 321.87 321.87 323.89 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.67 323.67 323.67 323.67 323.67 333.83 333.80 333.80 328.57 322.59 322.71 322.87 322.87 322.83 322.83 322.87 322.87 322.87 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82	351.54 350.51 360.51 360.51 355.73 365.73 364.59 374.28 347.15 347.35 347.35 347.35 347.35 347.37 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 355.94 352.06 357.00 357.20 355.08 355.04 355.05 355.06 355.07 355.06 355.07 355.08 355.08 355.08 355.08 355.08 3	379.74 376.11 366.56 371.03 371.03 377.03 357.43 359.26 357.43 359.26 357.43 359.26 357.43 359.26 357.43 359.26 355.10 355.10 355.10 355.10 366.43 376.59 366.43 376.59 377.60 377.50 366.43 366.43 376.59 366.43 366.23 366.43 376.59 377.60 377.50	0.0531 0.0465 0.0480 0.0534 0.0610 0.0534 0.0624 0.0524 0.05516 0.0624 0.05516 0.06624 0.05516 0.06624 0.0667 0.06648 0.0667 0.06648 0.0776 0.0550 0.0516 0.0550 0.0516 0.0455 0.0516 0.0550 0.0534 0.0550 0.0550 0.0550 0.0550 0.0521 0.0465 0.0550 0.0550 0.0521 0.0465 0.0550 0.0550 0.0550 0.0551 0.0550 0.0551 0.0550 0.0550 0.0551 0.0550 0.0550 0.0551 0.0550 0.0551 0.0550 0.0550 0.0551 0.0550 0.0551 0.0550 0.0550 0.0550 0.0551 0.05500000000	0.0502 0.0551 0.0596 0.0462 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain Grain CM microtexture Grain Mats-like network Mats-like network	27 28 29 30 1 1 2 3 3 4 4 5 6 6 7 7 7 8 9 9 10 112 13 4 4 5 6 6 7 7 7 8 9 9 10 112 12 13 14 15 6 6 6 7 7 7 7 8 9 9 10 112 12 3 3 4 4 4 5 6 6 6 6 6 7 7 7 7 8 9 9 9 10 11 12 12 3 3 4 4 4 4 4 5 6 6 6 6 6 6 6 6 6 6 7 7 7 7 7 8 9 9 9 10 11 12 12 14 14 14 15 6 6 6 6 6 6 6 6 6 6 6 7 7 7 7 7 7 8 9 9 9 10 11 12 12 14 14 15 16 6 6 6 6 6 6 6 7 7 7 7 7 7 7 8 9 9 9 9 10 112 112 112 112 112 112 112 112 112	130883.813 74990.048 77585.568 77585.568 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21	1624.996 1626.372 1626.728 1626.606 143 1.43 1.44 1.44 1.44 1.44 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 1817.172 1925.822 0.66860 0.6771 0.7118 0.6680 0.66880 0.66880 0.66880 0.66880 0.6721 0.66880 0.6721 0.66880 0.66936 0.66936 0.66936 0.66936 0.66952 0.66951 0.7035 0.66944 0.7035 0.66944 0.7035 0.66944 0.7035 0.66954 0.7035 0.7075 0.66954 0.7075 0.6697	29,949 28,779 26,921 26,921 26,251 3,22 3,30 3,27 3,34 3,40 3,34 3,40 3,34 3,40 3,34 3,40 3,34 3,34	0.7212 0.7122 0.7125 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7156 0.7061 0.6984 0.7131 0.7238 0.7061 0.7062 0.7766 0.7766 0.7727 0.7706 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7706 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7772 0.7707 0.7772 0.7772 0.7772 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.7726 0.7727 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7726 0.7727 0.7726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77726 0.77727 0.7776 0.77718 0.77	320.05 324.07 324.394 321.95 321.85 321.85 321.85 321.85 321.85 321.85 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.67 323.67 323.67 323.67 323.67 333.83 333.80 333.80 328.57 322.59 323.72 333.80 322.85 322.85 322.85 322.87 322.87 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82	351.54 350.51 360.51 360.51 355.73 365.73 364.59 371.51 347.15 347.15 347.15 347.15 347.15 357.73 352.07 352.66 354.15 355.94 352.66 354.15 355.94 352.66 354.15 355.94 355.94 355.94 355.94 355.94 355.94 355.95 355.96 355.90 355.90 351.12 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 359.08 3	379.74 376.11 376.13 376.13 376.13 376.13 376.13 377.03 357.48 357.26 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 355.10 345.72 355.10 345.77 356.31 366.43 377.50 354.82 366.43 377.50 354.82 366.43 377.50 354.82 366.43 376.58 375.35 366.43 376.58 375.35 366.43 354.83 366.23 366.43 376.58 377.50 354.82 366.43 355.10 354.82 366.43 355.10 354.82 366.43 355.83 355.83 355.83 355.83 377.07 355.05 377.07 355.01 366.74 377.07 377.07 377.07 377.07 377.07 366.74 377.07 377.30 366.74 377.07 377.30 366.74 377.92 377.07 366.74 377.92 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 367.44 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 366.75 377.92 336.94 366.75 377.92 336.94 366.75 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.75 376.95 377.92 336.94 366.95 376.95 377.92 336.94 366.95 376.95 377.92 336.94 376.95 376.95 376.95 376.95 377.92 336.94 376.95 376.95 376.95 376.95 377.92 336.94 376.95 376.95 376.95 376.95 376.95 377.92 336.94 376.95 376.95 376.95 376.95 376.95 377.92 376.95	0.0531 0.0465 0.0480 0.0534 0.0610 0.0534 0.0624 0.0524 0.0526 0.0524 0.05516 0.0662 0.0662 0.0662 0.0667 0.06648 0.0476 0.0550 0.0516 0.0476 0.0550 0.0516 0.0465 0.0465 0.0534 0.0550 0.0553 0.0465 0.0553 0.0465 0.0550 0.0553 0.0465 0.0550 0.0550 0.0551 0.0465 0.0550 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0551 0.0550 0.0550 0.0551 0.0550 0.0551 0.0550 0.0550 0.0550 0.0550 0.0550 0.0550 0.0550 0.0550 0.0551 0.0550 0.0550 0.0550 0.0550 0.0551 0.05500	0.0502 0.0551 0.0596 0.0545 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Gran Grain G	27 28 29 30 1 1 2 3 3 4 5 5 7 7 8 9 9 10 11 12 3 3 4 4 5 6 6 7 7 8 9 9 10 11 12 23 24 25 23 24 25 23 24 25 23 24 25 23 24 25 26 20 20 20 20 20 20 20 20 20 20 20 20 20	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.25 2.27 2.37 2.28 2.24 2.24 2.24 2.24 2.24 2.24 2.27 2.27 2.27 2.28 2.24 2.28 2.24 2.21 2.28 2.24 2.21	1626.972 1626.972 1626.728 1626.606 147 143 143 144 141 158 155 155 155 155 155 155 155 155 15	2878.699 2131.664 1817.172 1925.822 0.66771 0.6880 0.6880 0.6887 0.6781 0.6788 0.7005 0.6778 0.6985 0.7005 0.6985 0.7005 0.6985 0.6985 0.7005 0.6985 0.7035 0.6985 0.7035 0.6985 0.7035 0.6985 0.7035 0.6985 0.7035 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6985 0.7025 0.6975 0.6985 0.7072 0.6887 0.7072 0.6885 0.7075 0.6885 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.7075 0.707	29,949 26,921 26,221 26,251 3,22 3,32 3,32 3,32 3,32 3,32 3,32 3,3	0.7212 0.7122 0.7125 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7126 0.7131 0.7131 0.7133 0.7136 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7132 0.7131 0.7132 0.7131 0.7132 0.7131 0.7238 0.7112 0.7062 0.77145 0.7065 0.6841 0.6841 0.6903 0.7124 0.7065 0.7126 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77146 0.7705 0.77146 0.7705 0.77146 0.77146 0.77146 0.77146 0.77146 0.77147 0.77146 0.77147 0.77145 0.77145 0.77145 0.77145 0.77146 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77145 0.77146 0.77146 0.77146 0.77145 0.77150 0.77145 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0.77150 0	320.67 324.05 324.05 324.05 321.35 321.35 321.35 321.35 321.35 321.35 321.35 321.35 323.87 323.87 323.87 323.87 323.87 330.21 323.86 323.87 330.21 323.87 330.21 323.87 330.21 323.87 330.21 323.87 330.21 323.87 323.87 323.87 323.87 323.87 323.87 323.83 324.33 324.33 323.86 323.86 333.80 ΔT C* (2) 319.17 333.83 328.57 328.57 327.80 <t< td=""><td>351.54 330.51 361.16 330.51 361.27 365.73 374.28 344.38 347.35 347.35 347.35 347.35 347.35 347.35 347.35 347.35 352.65 353.01 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.77 355.94 352.65 352.77 355.94 355.00 357.41 355.00 357.70 355.98 355.00 357.79 358.87 358.40 359.65 359.86 358.40 359.84 359.84 359.84 3</td><td>379.74 376.11 376.11 376.12 377.03 377.03 337.03 353.26 339.61 335.26 339.61 335.26 339.61 335.26 339.61 335.26 339.61 335.26</td><td>0.0531 0.0465 0.0460 0.0534 0.0554 0.0620 0.0620 0.0624 0.0624 0.0624 0.06524 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Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Corain Grain Corain Coa Can Coa Can Coa Can Coa Can Co	27 28 29 30 1 1 2 3 3 4 5 5 6 6 7 7 8 9 9 10 11 12 3 3 4 4 5 5 6 7 7 8 9 9 10 20 11 12 3 13 14 5 5 7 7 8 9 9 10 11 12 3 13 14 5 5 7 7 7 8 9 9 10 11 11 12 3 13 14 5 5 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.25 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.31 2.28 2.44 2.42 2.31 2.28 2.44 2.42 2.31 2.28 2.44 2.42 2.17 1.59 3.18 3.18 3.19 3.28 3.19 3.28 3.10 3.19 3.28 3.10	1626.972 1626.972 1626.728 1626.606 147 143 144 144 144 158 155 155 156 146 166 166 166 166 166 166 16	2878.699 2131.664 1817.172 1925.822 0.6880 0.6880 0.6880 0.6887 0.6880 0.6887 0.6881 0.6985 0.6985 0.6985 0.6985 0.6985 0.6985 0.6985 0.6985 0.6881 0.6881 0.6881 0.6881 0.6881 0.6881 0.6881 0.6881 0.6965 0.6965 0.6965 0.6965 0.6965 0.6965 0.6965 0.6965 0.6985 0.6975 0.6985 0.7712 0.6985 0.7722 0.6975 0.6975 0.6975 0.6975 0.6975 0.6975 0.6975 0.6975 0.6975 0.7721 0.6975 0.7721 0.6975 0.7721 0.6975 0.7725 0.7721 0.6975 0.7725 0.7725 0.7725 0.7725 0.7725 0.7725 0.7725 0.6975 0.6955 0.7721 0.6855 0.7721 0.6855 0.7725 0.6975 0.6975 0.6975 0.6975 0.7725 0.6975 0.7725 0.7725 0.7725 0.7725 0.7727 0.6757 0.7725 0.7757 0.7757 0.7757 0.7757 0.7757 0.6757	29,949 26,921 26,221 26,251 3,22 3,27 3,32 3,32 3,32 3,32 3,32 3,32	0.7212 0.7122 0.7125 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7133 0.7133 0.7136 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7132 0.7131 0.7132 0.7131 0.7238 0.7112 0.7065 0.7045 0.6841 0.6841 0.6903 R _2(1) 0.7252 0.7065 0.7145 0.7025 0.7145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7076 0.77145 0.7075 0.77146 0.7075 0.77146 0.7075 0.77148 0.7053 0.77130 0.77130 0.77145 0.7075 0.77146 0.7075 0.77146 0.7053 0.77146 0.7053 0.77146 0.7053 0.77146 0.7053 0.77146 0.7053 0.77146 0.7053 0.77148 0.77150 0.77150 0.77150 0.77150 0.77150 0.77160 0.77160 0.77150 0.77150 0.77150 0.77160 0.77150 0.77150 0.77160 0.77150 0.77160 0.77150 0.	$\begin{array}{c} 320.05\\ 324.05\\ 324.05\\ 324.05\\ 321.35\\ 321.35\\ 321.35\\ 321.35\\ 321.35\\ 321.35\\ 321.35\\ 322.36\\ 322.36\\ 322.36\\ 322.36\\ 322.36\\ 322.36\\ 330.21\\ 322.36\\ 330.21\\ 322.36\\ 330.21\\ 322.36\\ 330.21\\ 322.36\\ 330.21\\ 322.36\\ 330.22\\ 330.21\\ 330.22\\$	351.54 330.51 340.51 350.51 351.64 352.51 361.16 352.52 340.83 342.83 342.83 347.53 347.53 347.52 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.65 352.77 355.76 355.00 357.72 355.00 357.72 355.00 357.72 355.00 357.79 358.87 358.87 358.87 359.86 359.86 359.86 359.86 359.86 3	379.74 376.11 366.56 377.03 376.13 376.13 376.13 377.03 385.26 385.26 385.26 385.26 385.26 385.26 336.27 336.27	0.0531 0.0465 0.0460 0.0534 0.0554 0.0624 0.0646 0.0646 0.0646 0.0646 0.0635 0.0645 0.0654 0.0655 0.0654 0.0655 0.0664 0.0655 0.0655 0.0664 0.0655 0.0655 0.0655 0.0665 0.0655 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0665 0.0665 0.0655 0.0665 0.0665 0.0655 0.0665 0.0665 0.0665 0.0655 0.0665 0.0665 0.0665 0.0655 0.0665 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0665 0.0655 0.0675 0.07770000000000000000000000000000000	0.0562 0.0551 0.0545 0.0545 0.0545 0.0545 0.0520 0.0520 0.0523 0.0523 0.0523 0.0525 0.0495 0.0536 0.0536 0.0536 0.0536 0.0538 0.0536 0.0538 0.0538 0.0538 0.0538 0.0538 0.0556 0.0538 0.0557 0.0458 0.0508 0.0508 0.0508 0.0508 0.0506 0.0508 0.0506 0.0508 0.0506 0.
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Lami	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Coan Coan Coan Coan Coan Coan Coan Coa	27 28 29 30 1 1 1 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 0 0 10 11 12 23 24 25 23 24 25 23 24 25 23 24 25 20 7 7 8 9 9 0 0 11 11 20 20 21 20 20 20 20 20 20 20 20 20 20 20 20 20	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.22 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.37 2.27 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355.86 355.98 355.98 355.98 355.98 355.96 355.96</td><td>379.74 376.11 366.56 377.03 376.11 366.56 377.03 380.13 357.40 357.40 353.61 354.91 364.30 377.30 365.91 354.82 366.23 366.23 377.30 377.00 377.07 365.91 366.23 365.91 365.91 366.23 377.20 377.07 365.91 366.23 366.23 377.35 366.23 377.07 365.91 366.23 366.25 377.35 366.23 377.35 377.35 366.23 377.35 366.23 377.35 366.23 377.35 366.23 377.35 377.35 366.23 377.35 366.23 377.35 366.23 377.35 366.23 377.35 366.23 377.35 375.35</td><td>0.0531 0.0465 0.0460 0.0534 0.0554 0.0624 0.0624 0.0624 0.0624 0.0624 0.06524 0.06524 0.06524 0.06546 0.06516 0.06648 0.06648 0.06648 0.06648 0.06546 0.06546 0.06549 0.077700000000000000000000000000000000</td><td>0.0502 0.0551 0.0545 0.0545 0.0545 0.0545 0.0545 0.0520 0.0527 0.0527 0.0523 0.0523 0.0525 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0535 0.0555</td></t<>	351.54 330.51.54 330.51.64 330.51.64 340.83 342.83 342.83 342.83 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Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Granular carbonaceous chert Granular	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Mats-like network Mats-like network	27 28 29 30 1 1 2 3 3 4 4 5 6 6 6 7 7 7 7 8 9 9 10 112 12 3 4 4 5 6 6 6 8 8 9 9 10 112 12 23 24 22 23 24 25 7 7 7 8 8 9 9 10 112 12 2 2 3 4 4 112 12 114 112 12 2 3 4 4 4 5 6 6 6 6 6 6 6 7 7 7 7 7 7 7 8 8 8 9 9 10 112 112 114 112 114 114 115 114 114 115 114 114 115 114 114	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.22 2.24 2.22 2.24 2.22 2.24 2.22 2.24 2.27 2.28 2.24 2.27 2.28 2.24 2.27 2.28 2.24 2.27 2.28 2.24 2.17 1.99 1.82 1.98 2.03 2.05 2.48	1624.996 1626.728 1626.728 1626.606 143 1.43 1.44 1.54 1.55 1.55 1.54 1.44 1.44 1.54 1.5	2878.699 2131.664 1817.172 1925.822 0.6860 0.6860 0.66771 0.7118 0.6680 0.6680 0.6683 0.6721 0.6782 0.6721 0.6680 0.6683 0.6721 0.6683 0.6723 0.6723 0.6723 0.6723 0.6733 0.6723 0.6733 0.6723 0.6733 0.6723 0.6733 0.6723 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.67724 0.66891 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.6695 0.67724 0.66891 0.6695 0.67724 0.6685 0.67725 0.6695 0.7725 0.6797 0.7725 0.6797 0.7725 0.6797 0.7725 0.7727 0.7725	29,949 28,779 26,921 26,921 26,251 3,22 3,30 3,27 3,34 3,40 3,34 3,34 3,34 3,34 3,34 3,34	0.7212 0.7122 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7173 0.7131 0.7133 0.7134 0.7133 0.7136 0.7061 0.6984 0.7131 0.7238 0.7061 0.7062 0.7062 0.7062 0.7766 0.7727 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7707 0.7708 0.7718 0.7718 0.7718 0.7728 0.7718 0.7728 0.7718 0.7727 0.7706 0.7718 0.7708 0.7718 0.	320.05 324.07 324.394 321.95 321.95 321.85 321.85 321.85 323.87 323.87 323.87 323.57 323.57 323.57 323.57 323.57 323.57 323.57 323.57 323.57 323.57 323.57 324.53 325.57 326.73 326.73 326.73 326.73 326.57 323.66 333.80 333.80 333.80 322.57.33 322.67.1 322.57.3 322.67.1 322.59.24 322.43 322.43 322.43 322.43.37 322.43.37 322.43.37 322.43.37 322.43 322.44 <td>351.54 350.51 360.51 360.51 355.73 360.51 355.73 367.15 377.15 377.15 377.15 377.15 377.75 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.08 354.15 356.11 357.08 357.00 357.34 358.97 358.97 358.97 358.97 358.97 358.97 359.08 359.08 359.08 3</td> <td>379.74 376.11 376.13 376.13 376.13 376.13 377.03 357.43 359.26 357.43 359.26 357.43 359.26 357.43 359.26 357.45 359.26 357.45 359.26 356.23 356.23 356.44 357.85 366.45 377.05 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.83 355.10 354.83 356.28 357.85 356.85 377.07 355.05 377.07 355.01 367.14 366.37 366.36 377.92 336.94 366.37 366.37 366.21 377.95</td> <td>0.0531 0.0465 0.04480 0.0453 0.0534 0.0610 0.0524 0.0524 0.0524 0.05516 0.0526 0.0562 0.0562 0.0562 0.0562 0.0562 0.05616 0.0476 0.05516 0.0476 0.05516 0.05516 0.05516 0.0455 0.05516 0.05516 0.05516 0.05516 0.05534 0.05534 0.05531 0.0465 0.05531 0.0465 0.0550 0.0550 0.05517 0.0550 0.05517 0.0550 0.05517000000000000000000000000000000000</td> <td>0.0562 0.0551 0.0596 0.0545 0.0545 0.0545 0.0545 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0527 0.0525 0.0525 0.0525 0.0555</td>	351.54 350.51 360.51 360.51 355.73 360.51 355.73 367.15 377.15 377.15 377.15 377.15 377.75 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.07 352.08 354.15 356.11 357.08 357.00 357.34 358.97 358.97 358.97 358.97 358.97 358.97 359.08 359.08 359.08 3	379.74 376.11 376.13 376.13 376.13 376.13 377.03 357.43 359.26 357.43 359.26 357.43 359.26 357.43 359.26 357.45 359.26 357.45 359.26 356.23 356.23 356.44 357.85 366.45 377.05 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.82 366.23 354.83 355.10 354.83 356.28 357.85 356.85 377.07 355.05 377.07 355.01 367.14 366.37 366.36 377.92 336.94 366.37 366.37 366.21 377.95	0.0531 0.0465 0.04480 0.0453 0.0534 0.0610 0.0524 0.0524 0.0524 0.05516 0.0526 0.0562 0.0562 0.0562 0.0562 0.0562 0.05616 0.0476 0.05516 0.0476 0.05516 0.05516 0.05516 0.0455 0.05516 0.05516 0.05516 0.05516 0.05534 0.05534 0.05531 0.0465 0.05531 0.0465 0.0550 0.0550 0.05517 0.0550 0.05517 0.0550 0.05517000000000000000000000000000000000	0.0562 0.0551 0.0596 0.0545 0.0545 0.0545 0.0545 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0527 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Granular carbonaceous ch	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Grain Grain CM microtexture Grain Mats-like network Mats-like network Grain Gr	27 28 29 30 1 1 2 2 3 4 4 5 6 6 6 7 7 7 8 8 9 9 10 112 12 13 4 4 5 6 6 6 6 6 7 7 7 7 8 8 9 9 10 112 112 114 115 16 16 16 17 2 2 3 4 4 5 5 6 6 6 6 7 7 7 7 8 8 9 9 10 112 12 2 3 4 4 4 5 5 6 6 6 6 6 6 6 6 6 6 6 7 7 7 7 7 7 7	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.47 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.22 2.24 2.22 2.24 2.22 2.24 2.22 2.24 2.27 2.28 2.24 2.12 2.17 1.99 1.82 1.98 2.03 2.05 2.48 2.12 2.12	1624.996 1626.372 1626.728 1626.606 143 1.43 1.44 1.54 1.54 1.54 1.55 1.55 1.44 1.44	2878.699 2131.664 1817.172 1925.822 0.6860 0.6860 0.6860 0.66771 0.7118 0.6680 0.6680 0.6680 0.6680 0.6781 0.6782 0.6782 0.6782 0.6782 0.6782 0.6783 0.6782 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6783 0.6889 0.6889 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6733 0.67724 0.6891 0.6733 0.67724 0.6891 0.6733 0.67724 0.6891 0.6733 0.67724 0.6891 0.6733 0.67724 0.6891 0.6733 0.67724 0.6735 0.6735 0.6735 0.6735 0.6735 0.6735 0.6795 0.6859 0.7775 0.6857 0.6857 0.6857 0.775 0.6857 0.6797 0.6792 0.6772 0.6792	29,949 28,779 26,921 26,921 26,251 3,26 3,27 3,30 3,27 3,340 3,27 3,340 3,347 3,344 3,349 3,376 3,377 3,377 3,376 3,376 3,376 3,377 3,377 3,377 3,376 3,376 3,377 3,377 3,377 3,376 3,377 3,376 3,377	0.7212 0.7122 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7131 0.7134 0.7133 0.7156 0.7061 0.6984 0.7131 0.7238 0.7061 0.7062 0.7062 0.7062 0.7766 0.7727 0.7706 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7706 0.7718 0.7707 0.7706 0.7718 0.7707 0.7706 0.7718 0.7707 0.7706 0.7718 0.	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 323.89 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.67 323.67 323.67 333.83 333.80 333.80 333.80 333.80 328.57 322.67 333.80 333.80 333.80 333.80 328.57 322.82 323.71 324.69 322.71 322.82 322.82 322.82 322.82 322.82 322.82 322.82 322.82	351.54 350.51 360.51 360.51 357.57 365.71 371.51 347.15 347.15 347.15 347.15 347.15 347.15 347.15 357.77 352.07 353.15 347.15 357.72 352.66 354.15 355.94 352.66 357.72 355.04 351.11 315.04 314.72 295.08 ΔTC (3) 357.73 355.04 355.734 355.82 355.90 355.90 355.90 355.90 344.82 320.23 333.92 344.82 363.40 355.90 344.82 363.40 355.90 <	379.74 376.11 366.56 371.03 377.03 377.03 357.83 359.26 3357.83 359.26 357.83 359.26 357.83 359.26 357.84 357.27 359.26 355.10 345.72 355.10 345.45 355.10 345.45 366.45 356.23 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 354.82 366.45 355.10 354.82 366.45 355.83 366.45 355.83 366.23 366.45 355.83 366.23 366.45 355.83 366.25 355.83 366.25 355.83 366.25 355.83 355.85 377.27 377.07 355.01 367.14 365.36 377.27 377.07 355.01 366.75 377.27 377.07 355.01 366.75 377.27 377.07 355.01 366.75 377.92 336.94 366.37 367.14 365.83 377.92 336.94 365.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 355.83 357.92 356.91 355.83 355.83 357.92 356.91 355.84 355.83 357.92 356.91 357.92 356.91 357.92 356.91 357.92 357.92 356.91 357.92 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 357.92 356.91 355.83 357.92 356.91 357.92 356.91 357.92 356.91 357.92 357.92 356.91 355.84 357.92 357.92 356.91 357.92 357.92 356.91 357.92 357.92 356.91 357.92 357.92 356.91 357.92 356.91 357.92 357.92 357.92 356.91 357.92 356.91 357.92 357.92 357.92 356.91 357.92 356.91 357.92 357.92 357.92 356.91 357.92 356.91 357.92 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 357.92 356.91 356.91 357.92 356.91 356.91 356.91 357.92 356.91 356.91 357.92 356.91 356.91 356.91 357.92 356.91 356.91 356.91 357.92 356.91 356.91 356.91 356.91 357.92 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.91 356.92 356.91 356.92 3	0.0531 0.0465 0.04480 0.0453 0.0534 0.0610 0.0524 0.0624 0.0524 0.05516 0.0624 0.0624 0.05516 0.06624 0.0667 0.06648 0.0667 0.06648 0.0476 0.0550 0.0516 0.0476 0.0551 0.0551 0.0551 0.05516 0.05534 0.05534 0.05534 0.05534 0.05531 0.0465 0.0550 0.05510 0.0550 0.05512 0.0471 0.05547 0.05527 0.05517 0.05527 0.05517000000000000000000000000000000000	0.0562 0.0551 0.0596 0.0545 0.0545 0.0545 0.0545 0.0520 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0527 0.0525 0.0527 0.0525 0.0525 0.0525 0.0555
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Caraular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Granular carbonace	D4A D4A D4A D4A D4A D4A D4A D4A D4A Sample C2C C2C	Grain Corain Grain Corain Coa Can Coa Coa Coa Coa Coa Coa Co	27 28 29 30 1 1 2 2 3 4 4 5 6 6 7 7 7 8 9 9 10 112 12 13 4 4 5 6 6 7 7 7 8 9 9 10 112 112 114 115 16 16 17 17 22 23 24 25 24 25 24 25 24 25 24 25 24 25 24 25 24 25 24 25 26 27 27 26 27 27 27 27 27 27 27 27 27 27 27 27 27	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.21 2.21 2.21 2.21 2.21 2.21 2.25 2.22 2.24 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.37 2.27 2.31 2.31 2.28 2.44 2.42 2.31 2.39 2.44 2.42 2.17 1.82 1.88 2.03 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.05 2.48 2.12	1624.996 1626.372 1626.728 1626.606 143 1.43 1.44 1.54 1.55 1.55 1.44 1.44 1.54 1.55 1.55	2878.699 2131.664 1817.172 1925.822 0.6860 0.6860 0.66771 0.7118 0.6680 0.6680 0.6680 0.6683 0.6721 0.6683 0.6721 0.6683 0.6721 0.6683 0.6721 0.6683 0.6721 0.6683 0.66953 0.66953 0.66953 0.66953 0.66954 0.7035 0.66891 0.7725 0.66854 0.7725 0.66854 0.7775 0.66854 0.7775 0.66854 0.7775 0.66875 0.7775 0.66875 0.7775 0.66875 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.66795 0.66775 0.67755 0.6	29,949 26,921 26,221 26,251 3,22 3,27 3,32 3,32 3,32 3,32 3,32 3,32	0.7212 0.7122 0.7122 0.7125 0.7170 0.7097 0.7175 0.7175 0.7175 0.7175 0.7175 0.7131 0.7133 0.7134 0.7133 0.7136 0.7061 0.6984 0.7131 0.7238 0.7061 0.7062 0.7062 0.7766 0.7766 0.7766 0.7727 0.7706 0.7707 0.7706 0.7707 0.7706 0.7707 0.7708 0.7718 0.7718 0.7708 0.7718 0.7718 0.7708 0.7718 0.7708 0.7718 0.7708 0.7718 0.7718 0.7708 0.7719 0.7719 0.	320.05 324.07 324.394 321.95 321.85 321.87 321.87 321.87 321.87 321.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 324.57 325.67 326.73 326.73 326.73 326.73 326.73 326.73 326.73 326.73 333.63 333.80 333.80 322.857 3228.57 322.433 322.433 322.433 322.433 322.433 322.433 322.433 322.433 322.433 322.423.97 322.443 <	351.54 350.51 360.51 360.51 357.57 365.71 371.51 347.15 347.15 347.15 347.15 347.15 347.15 357.73 352.07 352.07 352.07 352.07 352.07 352.66 354.72 350.82 351.11 351.5.04 314.72 355.08 357.74 355.08 357.73 355.08 355.10 357.34 355.08 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355.90.63 355	379.74 376.11 366.56 371.03 376.02 371.03 377.03 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 357.48 359.26 356.28 356.88 377.07 355.06 357.92 336.94 366.37 366.37 366.28 357.92 336.94 357.92 336.94 357.92 336.94 350.88	0.0531 0.0465 0.04480 0.0453 0.0534 0.0610 0.0524 0.0524 0.0524 0.05516 0.0526 0.05716 0.0662 0.06627 0.06648 0.0476 0.05516 0.0476 0.05516 0.05516 0.0476 0.05516 0.0476 0.05516 0.0475 0.05516 0.0455 0.05516 0.05516 0.05534 0.05534 0.05534 0.05531 0.0465 0.0550 0.05510 0.05521 0.04717 0.05547 0.05557 0.05517000000000000000000000000000000000	0.0562 0.0551 0.0556 0.0556 0.0545 0.0545 0.0545 0.0527 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.0552 0.05552 0.05552 0.0556 0.0556 0.0556 0.05508 0.05508 0.05508 0.05508 0.05578 0.05578 0.0578 0.0528 0.0578 0.0578 0.0578 0.0578 0.0528 0.0578 0.0578 0.05544 0.05544 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.05540 0.0
Granular carbonaceous chert Granular carbonaceous chert Granular carbonaceous chert Laminated black chert Caraular cabonaceous chert Granular cabonaceous chert Granu	D4A D4A D4A C2C C2C C2C C2C C2C C2C C2C C2C C2C C2	Grain Grain	27 28 29 30 1 1 2 3 3 4 5 5 6 6 7 7 8 8 9 10 11 12 23 24 25 26 6 7 7 8 9 10 11 12 23 24 25 26 27	130883.813 74990.048 77585.568 R ₁ 2.18 2.10 2.17 2.31 2.21 2.21 2.21 2.21 2.21 2.27 2.37 2.27 2.27 2.27 2.27 2.37 2.27 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.27 2.37 2.27 2.37 2.27 2.27 2.37 2.31 2.38 2.40 2.44 2.42 2.10 2.17 1.82 1.88 2.03 2.05 2.48 2.12 2.12 2.12 2.12 2.39	1626.972 1626.972 1626.728 1626.606 147 143 144 143 144 158 155 155 155 156 144 144 144 144 144 144 158 159 139 139 139 139 139 139 139 13	2878.699 2131.664 2131.664 6.6771 0.6880 0.6880 0.6887 0.6880 0.6887 0.6887 0.6887 0.6887 0.6887 0.6887 0.6887 0.7015 0.6771 0.6788 0.6788 0.7005 0.6895 0.7005 0.6895 0.6895 0.6895 0.6895 0.6895 0.6895 0.6891 0.6891 0.6891 0.6891 0.6891 0.6891 0.6895 0.7057 0.6881 0.6297 0.66881 0.6723 0.6725 0.6955 0.7035 0.6735 0.6955 0.7035 0.6957 0.6881 0.6297 0.6695 0.7721 0.6957 0.7072 0.6957 0.6957 0.6957 0.6957 0.6957 0.6957 0.7072 0.6957 0.6757 0.6759 0.6757 0.6759 0.6757 0.6759 0.6757 0.6759 0.6757 0.6759 0.6757 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.6759 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590 0.67590000000000000000000000000000000000	29,949 26,921 26,221 26,251 3,22 3,27 3,27 3,27 3,27 3,27 3,27 3,27	0.7212 0.7122 0.7125 0.7125 0.7170 0.7175 0.7175 0.7175 0.7175 0.7175 0.7181 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7131 0.7288 0.7113 0.7131 0.7288 0.7113 0.7288 0.7112 0.7061 0.7061 0.7062 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7065 0.7145 0.7076 0.77146 0.7076 0.7076 0.7076 0.70708 0.7073 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7038 0.7118 0.7118 0.7038 0.7118 0.7128 0.7051 0.7128 0.7065 0.7146 0.7076 0.7146 0.7076 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128 0.7058 0.7128	320.05 324.07 323.94 321.95 321.95 321.85 323.97 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 323.87 324.43 324.43 324.43 324.43 324.43 324.43 324.53 324.53 324.53 324.53 324.53 324.53 324.53 333.80 324.53 333.80 324.53 324.53 324.53 325.54 322.87 322.87 322.87 322.87 322.87 322.87 32	351.54 330.51 361.16 370.51 361.16 370.51 361.16 371.54 371.54 372.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 374.35 375.36 375.37 375.36 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 375.37 37	379.74 376.11 366.56 377.03 377.03 377.03 380.13 377.03 380.13 377.03 380.13 377.03 380.13 377.03 377.03 362.56 377.30 377.05 375.05 377.05 377.05 375.05 377.05 375.05 377.05 375.05 377.05 375.05 377.05 375.05 377.05 375.05 37	0.0531 0.0465 0.0460 0.0534 0.0554 0.0624 0.0624 0.0524 0.0524 0.0524 0.05251 0.0624 0.05516 0.0654 0.06546 0.05516 0.05516 0.05516 0.05519 0.05519 0.0645 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05519 0.05510 0.0551 0.0457 0.05510 0.05511 0.05551 0.05511 0.055510000000000	0.0502 0.0551 0.0596 0.0545 0.0545 0.0545 0.0545 0.0520 0.0523 0.0555 0.0495 0.0536 0.0536 0.0536 0.0538 0.0536 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0538 0.0556 0.0458 0.0525 0.0492 0.0508 0.0508 0.0508 0.0508 0.0508 0.0558 0.0508 0.05588 0.05588 0.05588 0.055880.05588 0.05588 0.055880.05588 0.05588