Supplementary Material

Paper: Serra Sul diamictite of the Carajás Basin (Brazil): A Paleoproterozoic glaciation on the Amazonian craton

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Geology

Table of contents

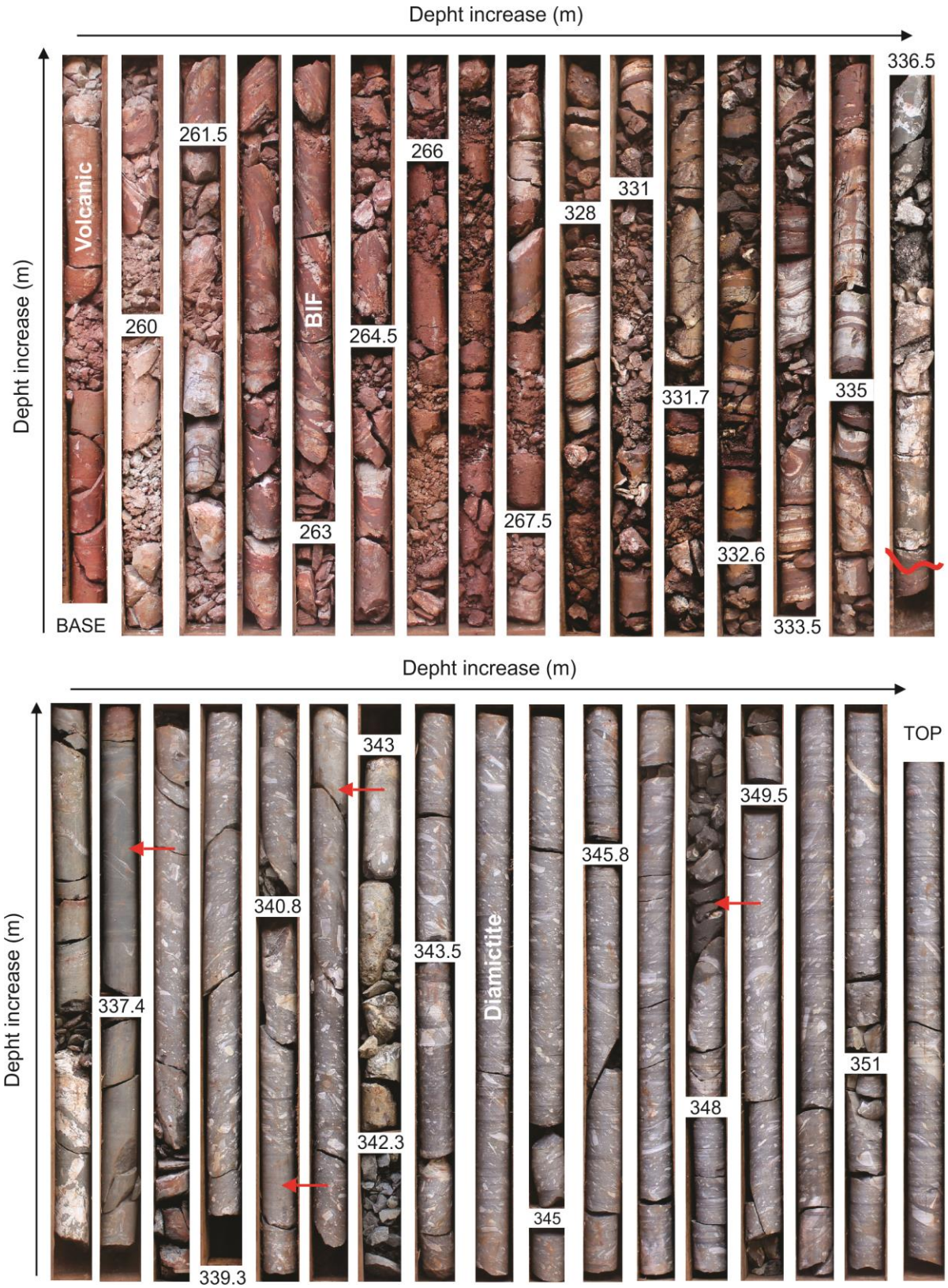


Figure DR1. Photograph of the drill core SSD-FD927 showing the contact (unconformity) between volcanic rock and BIF of the Neoarchean Grão-Pará Group and diamictite and black shale of the Serra Sul Formation (foliated to massive diamictite facies association). Arrows point to shale intervals that are interbedded with diamictite. The sedimentary structures indicate that the succession is stratigraphically inverted.

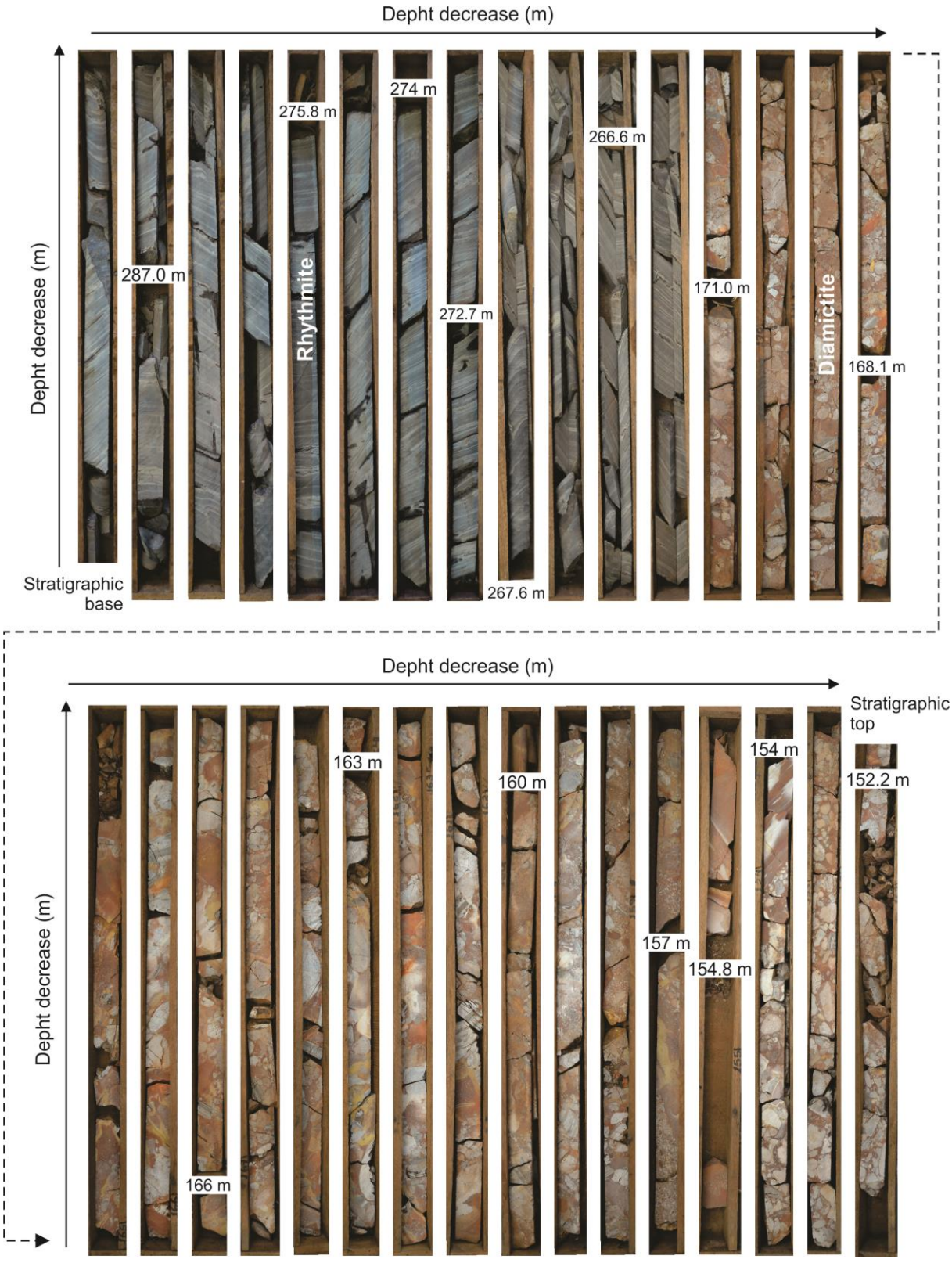
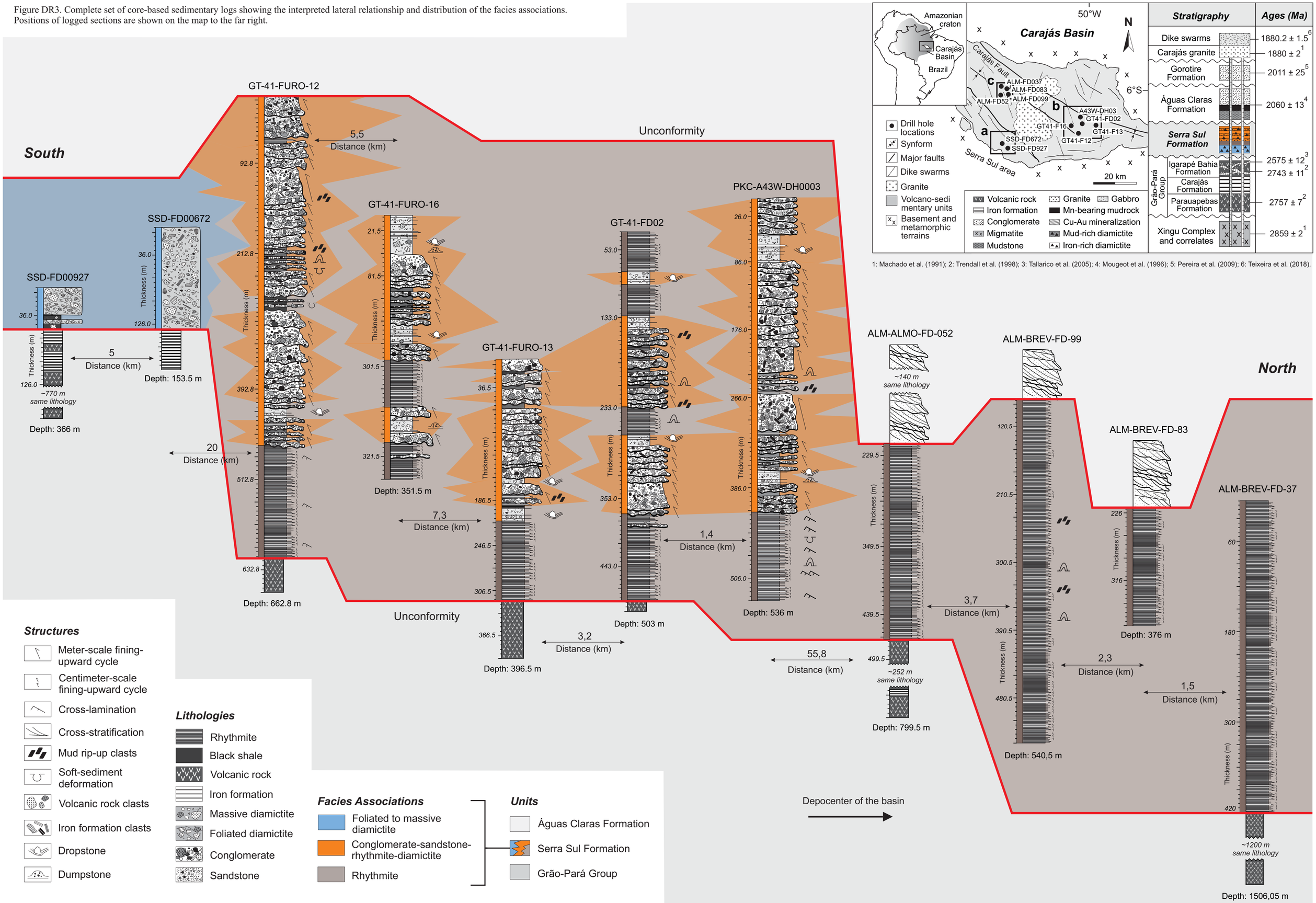


Figure DR2. Photograph of the drill core GT41-F13 showing the contact between the rhythmite facies association at the base, and conglomerate-sandstone-rhythmite-diamictite facies association at the top. Note that the stratigraphy is not inverted.

Figure DR3. Complete set of core-based sedimentary logs showing the interpreted lateral relationship and distribution of the facies associations. Positions of logged sections are shown on the map to the far right.



1: Machado et al. (1991); 2: Trendall et al. (1998); 3: Tallarico et al. (2005); 4: Mougeot et al. (1996); 5: Pereira et al. (2009); 6: Teixeira et al. (2018).

Table DR4. GPS coordinates of boreholes.

#Area a

Borehole	Latitude	Longitude	Date of description
SSD-FD00927	-6.38038850692	-50.3054460162	30th May 2018
SSD-FD00672	-6.35261051256	-50.3521129974	30th May 2018

#Area b

Borehole	Latitude	Longitude	Date of description
GT-41-FURO-12	-6.30288813137	-50.16877829	30th November 2017
GT-41-FURO-16	-6.2687212183	-50.2023896165	01th December 2017
GT-41-FURO-13	-6.26927683397	-50.1357224653	30th November 2017
GT-41-FD02	-6.25872118821	-50.1626670969	05th December 2017
PKC-A43W-DH0003	-6.25149891073	-50.1735005029	13th November 2015

#Area c

Borehole	Latitude	Longitude	Date of description
ALM-ALMO-FD052	-6.02955267811	-50.6240591362	06th December 2017
ALM-BREV-FD-99	-6.01816374201	-50.5935033509	21th June 2015
ALM-BREV-FD-83	-6.00038584039	-50.6068367659	18th June 2015
ALM-BREV-FD-37	-5.99871915223	-50.620170194	12th June 2015

Table DR5. Terrigenous lithofacies of the Serra Sul Formation.

Lithofacies	Description	Processes	Depositional environment
Massive diamictite	Unstratified and unsheared. The matrix is very poorly sorted and composed of micrometer-scale fragments of quartz and magnetite, and sometimes by mud. The clasts comprise chert, BIF-derived grains, and volcanic rock fragments. The clasts vary from angular to well-rounded. Faceted clasts occur widely. There are dropstones and dumpstones.	Glacial erosion of the bedrock (BIF and volcanic rock); ice-rafted debris associated with sedimentation by suspension	Subglacial coastal and marine setting
Foliated diamictite	Stratified and sheared. The matrix is very poorly sorted and composed of quartz and magnetite. Faceted, flattened, rotated, boudinaged, sheared, and lens-shaped clasts are widespread. The clasts are pebble to cobble-sized, vary in shape from very angular to rounded, and comprise chert, BIF-derived clasts, and volcanic rock fragments.	Glacial erosion (rock flour) of the bedrock (BIF and volcanic rock) associated with glaciotectonic deformation	Subglacial coastal
Black shale	Laminated and enriched in organic matter. Tabular geometry (inferred).	Sedimentation by suspension associated with the preservation of organic matter	Subglacial coastal
Rhythmite	Even parallel laminations. Composed of millimeter-scale to centimeter-scale intercalated fine-grained sandstone and argillite. Sulfides are disseminated in the sandstone layers. Ball-and-pillow, flame, and convolute laminations occur at facies contacts. Cross-laminae occur locally in the sandstone beds.	Regular alternation of sedimentation by traction and suspension; deposition by very low-density turbidite currents; plastic adjustments resulting in soft-sediment deformation; starved ripples	Basin floor (turbidite)

Conglomerate	Unstratified to weakly cross-stratified. Concave-up geometry (inferred). The clasts vary in size from pebbles to cobbles, subangular to well-rounded, and are composed of fragments of chert, BIF-derived clasts, and volcanic rock. The matrix varies from sandy to granular.	Deposition by high-density turbidity current	Glaciogenic submarine fan
Sandstone	Massive to weakly cross-stratified. Fine-grained to coarse-grained. The sand grains are composed of chert and quartz. Very well- to poorly sorted	Deposition by high-density turbidity current associated with a decline in velocity	Glaciogenic submarine fan

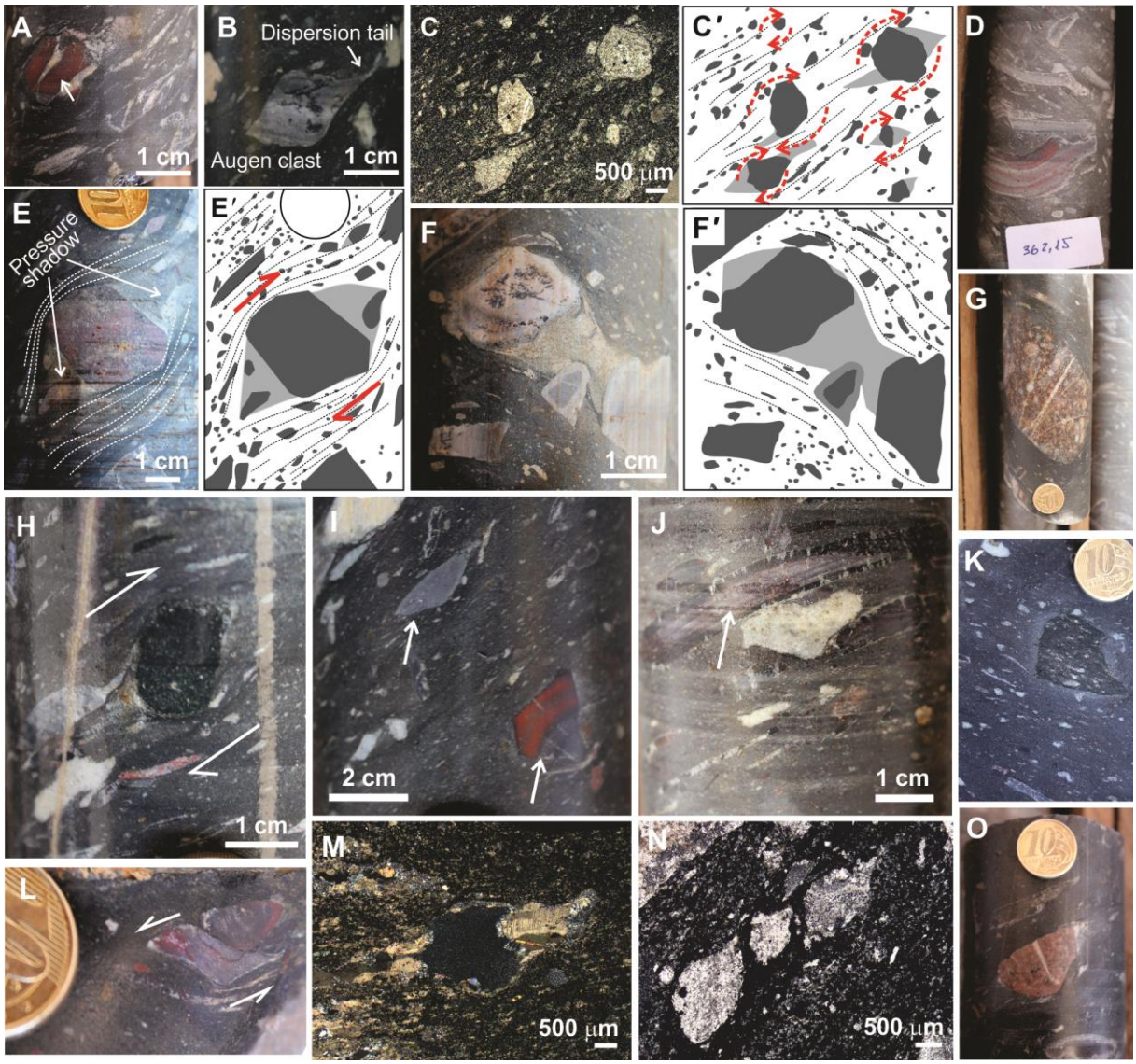


Figure DR6. Images of the main features observed in subglacial diamictite (foliated to massive diamictite facies association). A: Fractured and boudinaged clast of felsic volcanic rock (arrow). B: Augen clast of chert with a well-developed dispersion tail. C and C′: Photomicrograph (plane polarized light, 5x) and line interpretation of foliated diamictite showing faceted and rotated chert clasts with an asymmetrical pressure shadow. D: Several tabular BIF clasts scattered randomly in a fine-grained matrix. E and E′: Image and line interpretation of a faceted and rotated felsic volcanic rock (rhyolite) clast with an asymmetrical pressure shadow. F and F′: Image and line interpretation showing a classical boudinaged chert clast immersed in a poorly sorted and fine-grained matrix. G: Porphyritic volcanic rock clast suspended in a fine-grained matrix. The coin is 2 cm in diameter. H: Sheared clast of mafic volcanic rock with an asymmetrical pressure shadow. I: Flattened and faceted clasts of chert and BIF (arrows). J: Flattened clasts of BIF and chert showing fractures along the borders (arrow). K: Mafic volcanic rock clast embedded in a dark-colored and fine-grained matrix. L: Sheared clast of a BIF. M: Photomicrograph (cross-polarized light, 10x) showing a sheared chert clast with an asymmetrical pressure shadow composed of dolomite and quartz. N: Photomicrograph (plane polarized light, 10x) showing a micro-boudinaged chert clast. O: Faceted felsic volcanic rock with a pressure shadow exhibiting fractures perpendicular to foliation. The coin is 2 cm in diameter.

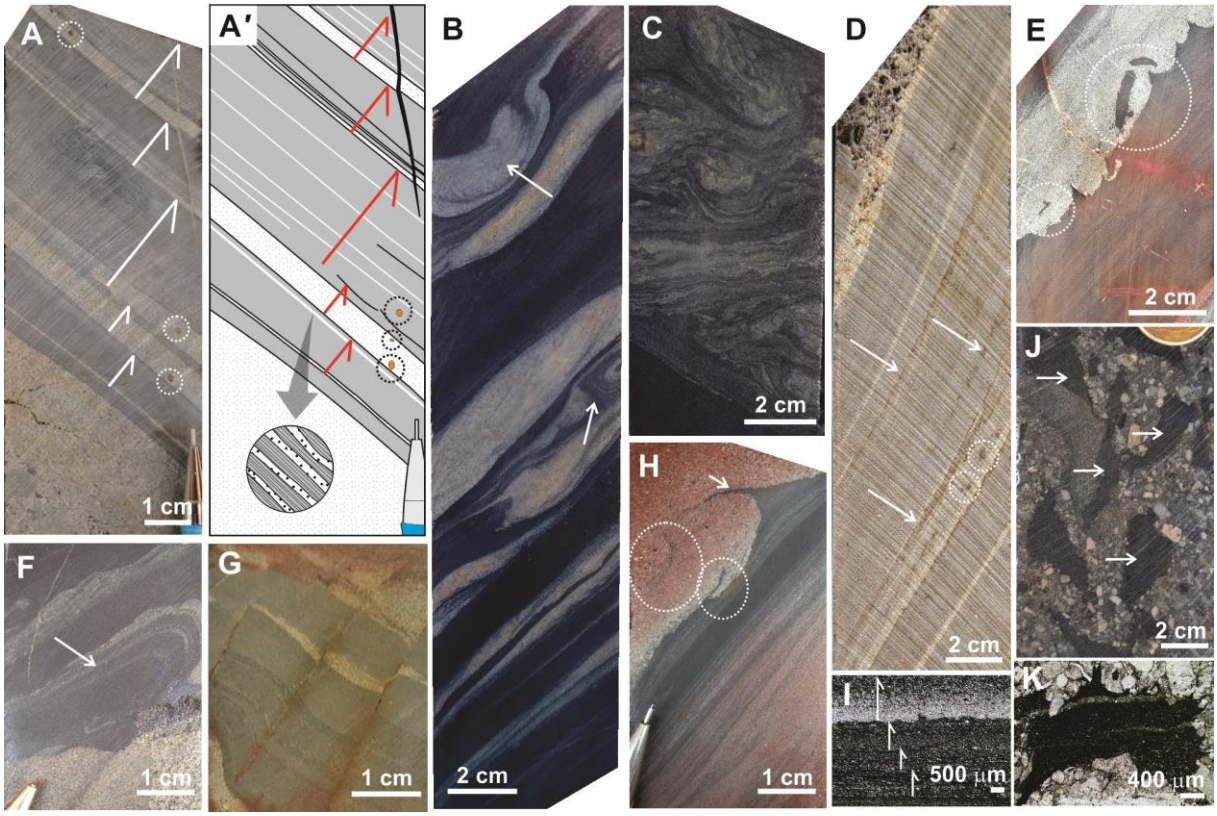


Figure DR7. Images of the main features observed in rhythmite (rhythmite facies association). A and A′: Image and line interpretation showing centimeter-scale fining-upward cycles between sandstone with normal gradations and mudstone. B: Black shale interbedded with fine-grained sandstone with normal gradation (rhythmite). Soft-sediment deformation (e.g., ball-and-pillow and convolute lamination) is widely developed contact zone between these two lithotypes. Cross-laminae sandwiched by muddy beds (starved ripples) occur locally and sulfide occurs within the sandstone layers. C: Completely convoluted sandy bed above an undeformed muddy bed. D: Rhythmite showing sulfide (arrows) disseminated in beds of fine-grained sandstone. E: Mud rip-up clasts (circles) in the base of a sandstone bed. F: Convoluted laminae. G: Syndepositional fault. H: Erosive contact between mudstone and sandstone showing flame (arrow) and curled mud flakes suspended at the base of the sandy bed (circles). I: Photomicrograph (plane polarized light, 5x) showing micrometer-scale fining-upward cycles between sandstone with normal gradation and mudstone. J: Several mud rip-up clasts (arrows) suspended in a conglomerate bed. K: Photomicrograph (plane polarized light, 5x) showing a mud clast deformed within a sandstone layer.

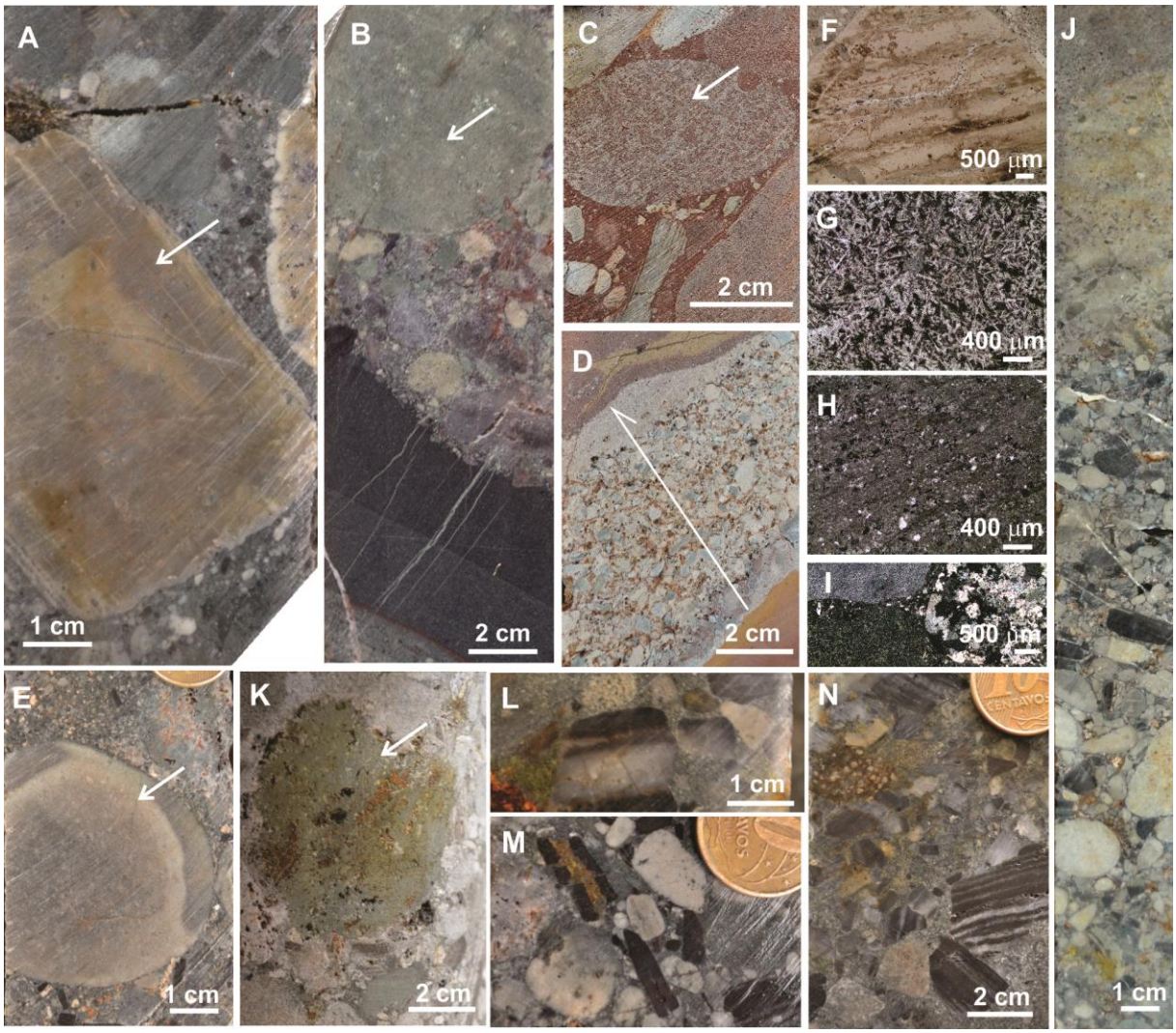


Figure DR8. Images of the main features observed in sandstone and clast-supported conglomerate (conglomerate-sandstone-rhythmite-diamictite facies association). A: Clast-supported conglomerate with faceted volcanic rock clasts (arrow). B: Clast-supported conglomerate with rounded volcanic rock clasts above a mudstone bed. C: Rounded volcanic rock clast (arrow) showing punctuated contact with other clasts in a clast-supported conglomerate. D: Conglomerate bed with normal gradation (arrow). E: Rounded volcanic rock clast (arrow) embedded in a sandy/conglomeratic matrix. F-H: Photomicrographs (plane polarized light, 5x) showing chert, volcanic rock, and volcanoclastic rock clasts, respectively. I: Photomicrograph (cross-polarized light, 5x) showing different volcanic to subvolcanic rock clasts. J: Fining-upward cycle showing a conglomerate with normal gradation trending up-section to massive sandstone. K: Mineralized mafic volcanic rock clasts (arrow) in a clast-supported conglomerate. L-N: Clast-supported conglomerate showing BIF, iron chert, mineralized volcanic rock, and mafic to felsic volcanic/subvolcanic rock clasts. The coin is 2 cm in diameter.

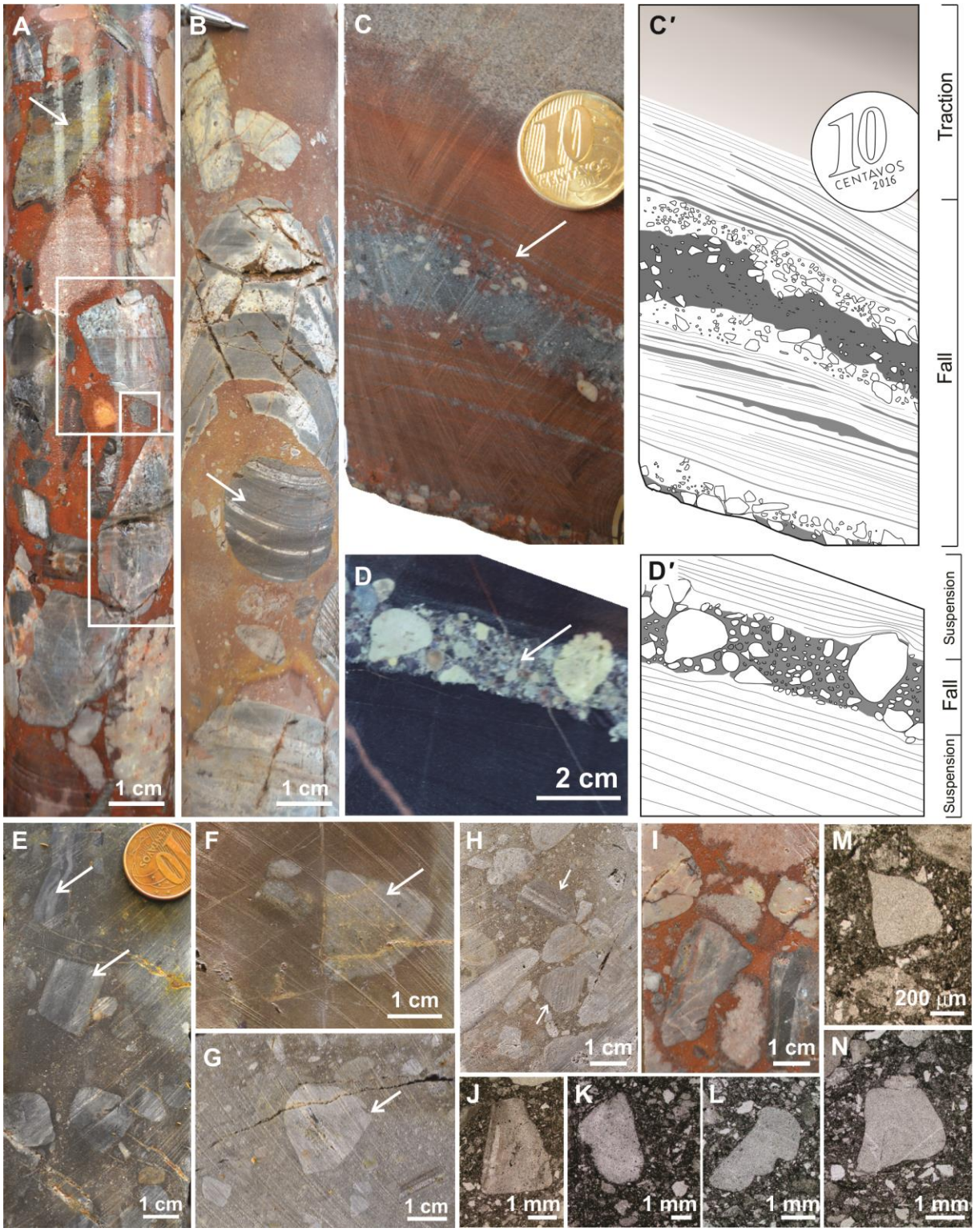


Figure DR9. Images of the main features observed in diamictite (conglomerate-sandstone-rhythmite-diamictite facies association). A: Clasts of mineralized volcanic rock (arrow), chert, and BIF suspended in a mud-rich matrix. Some faceted clasts are perfect elongated pentagons (boxes). B: BIF clasts, varying in shape from faceted to well-rounded (arrow), scattered in a mud-rich matrix. C-C′ and D-D′: Images and line interpretations showing a dumpstone structure defined by mounds of coarse-grained clasts (arrows) of volcanic rock, chert, and BIF suspended in and sandwiched by mudstone beds. E: Chert and BIF clasts with high dip angles (arrows) suspended in a mud-rich matrix. F and G: Faceted chert clast (arrows) suspended in a

poorly-sorted mud-rich matrix. H-I: Clasts of chert, BIF and volcanic rock, sometimes faceted (arrows), randomly scattered in a muddy matrix. J-N: Photomicrograph (plane polarized light, 5x) showing several faceted chert clasts in a poorly-sorted mud-rich matrix.

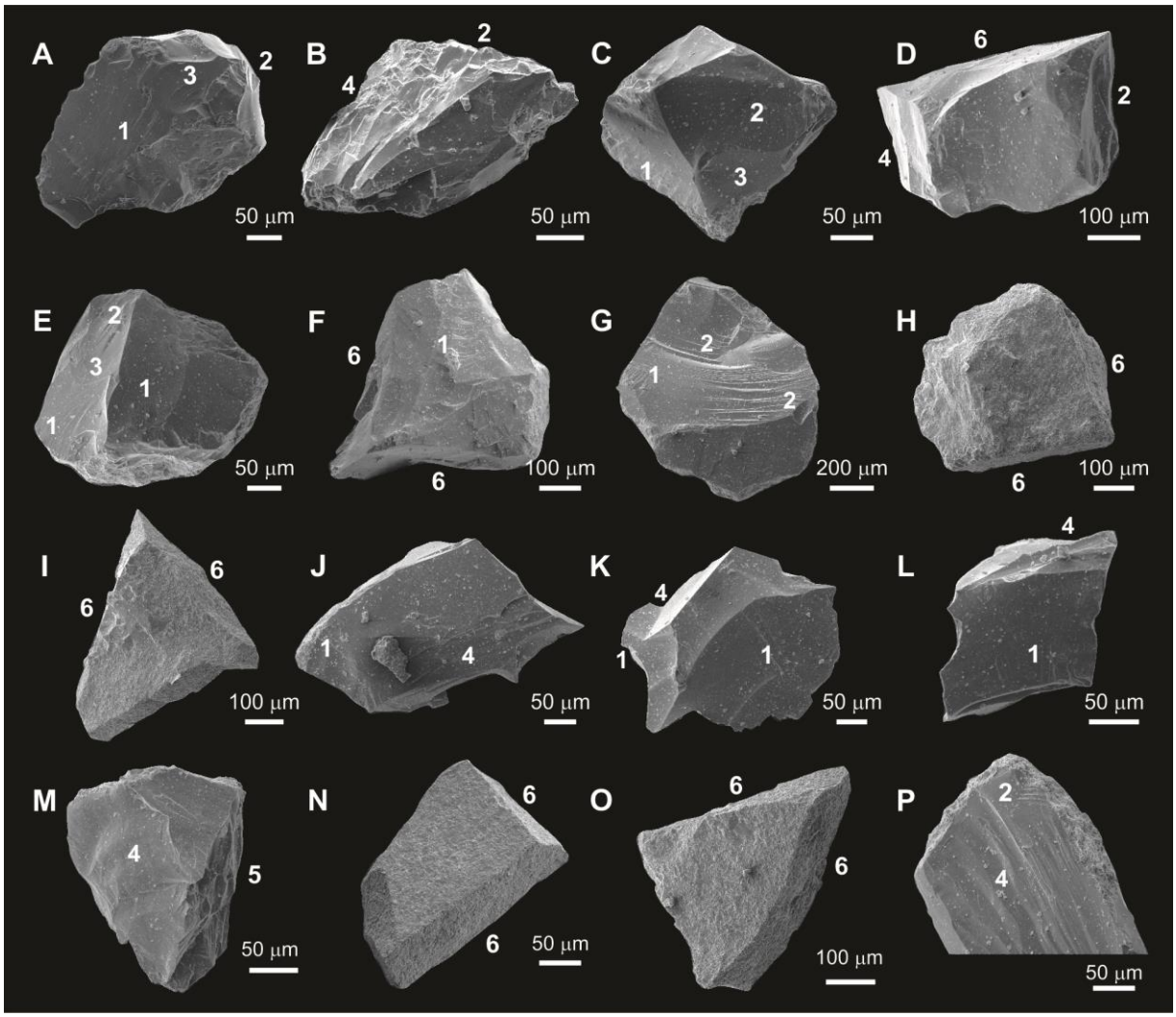


Figure DR10. Scanning electron microscope (SEM) images showing microtextures observed on very angular quartz sand grain surfaces: subparallel fractures (1), steps (2), conchoidal fractures (3), grooves (4), crushed surfaces (5), and smoothed surfaces (6).