Solid Earth Discuss., 7, C677–C695, 2015
www.solid-earth-discuss.net/7/C677/2015/

Solid Earth
Discussions
Open Access

Interactive comment on "Jurassic–cretaceous deformational phases in the Paraná intracratonic basin, southern Brazil" *by* A. J. Strieder et al.

A. J. Strieder et al.

adelirstrieder@uol.com.br

Received and published: 19 May 2015

Interactive Reply to "Anonimous Referee #1 Comment" on "Jurassic–Cretaceous deformational phases in the Paraná intracratonic basin, southern Brazil" by A.J. Strieder et al. Submitted to Solid Earth (sed-7-1263-2015) A. J. Strieder, R. Heemann, P. A. R. Reginato, R. B. Acauan, V. A. de Amorim, and M. Z. Remde adelirstrieder@uol.com.br

Authors would like to thank Anonymous Referee #1 for providing a detailed evaluation of the manuscript. These detailed and constructive comments enabled Authors to realize some presentation problems for the main subject of the manuscript. In this way, those problems were solved to emphasize the aims and goals of the manuscript, according the Referee suggestions. The detailed discussion about these aspects is addressed in the Authors' Response section (below). This reply is itemized in the se-

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

quence the Referee comments' appear, just to make the discussion clear to the reader, and to follow SE Journal directives. Then, Referee comments are shown in italics just to differentiate them from Authors' comments, that follows in regular font. The reviewed manuscript is attached as a supplementary file, according SE Journal rules.

1 Comments from Anonymous Referee #1, 23 Apr 2015 (RC C514) "This manuscript deals with structural analysis survey conducted within the Serra Geral and the Botucatu formations with the aim to evaluate the paleostress ïňĄeld during the Jurassic to Cretaceous period in the Paraná Basin. The Authors provide (i) meso-scale examples of the observed deformation structures, (ii) a basic regional-scale geological overview, and (iii) analysis of the brittle structures focused mainly on stress inversion techniques applied to fault-slip data. Large part of the manuscript is centred on the paleostress inversion. In my opinion, the present form of the manuscript needs for extensive revisions before to be accepted for publication on Solid Earth. I added my major and minor comments/suggestions in the attached ïňĄle, and I resume here: - The Introduction does not explain the real geological problem. The present Introduction reports the list of the previous works. It is not clear how the work by Strieder and co-authors should represent a progress in the knowledge of the tectonic evolution of the Paranà Basin. In general, the Introduction should be rewritten and re-organised; - A "Geological Setting" completely lacks. Although some information have been provided within the Introduction, the Authors are forced to provide the geological framework for the Paranà Basin. In particular, the main Mesozoic tectonic stages are welcomed (deformational phases listed in Table 1 are not enough, and they have to be detailed within the text); - The methodology paragraph (paragraph #2) is not well organised. It mixes methods and a preliminary report of results. It is not clear which was the rationale used by the Authors (why they focused on the Serra Geral Fm; which is the main goal of the structural analysis; . . .). Some analytical parts of this paragraph can be moved in an Appendix; - Data presentation is elusive. Deformation structures are not described in detail. The Authors mainly focused on the kinematic and geometric parameters of these structures, although some representations (the π diagram, the balanced cross-section) are

SED
7, C677–C695, 2015

questionable (see my comments in the attached ïňĄle); - The discussion of the results is centred on the stress states of the deformation phases. Anyway, a tectonic scenario framing the deformational phases (D1 and D2) is essential to me for reinforcing the scientiïňĄc message of this work. In particular, I suggest a tectonic scenario for illustrating the regional and meso-scale, major and minor structures that developed under the reconstructed constrictional deformation condition; - The Conclusion is not at the point and does not explain the real novelty from this work; - Some ïňĄgures should be improved (see the attached ïňĄle) (Fig. 18 is wrong, I suppose)."

2 Authors' response The Referee made detailed comments and added supplementary note on manuscript PDF that could help Authors in improvement of the original manuscript. The referee, in his introductory remark, notes that the present manuscript (sed-7-1263-2015) is devoted to structural analysis of deformation upon Serra Geral and Botucatu formations (upper sequences of the Paraná Basin). And, that the basis for structural analysis is fault-slip data inversion. Then, as a manuscript on structural analysis of uppermost sequence of the Paraná Basin, it follows Turner & Weiss (1963, p. 3-11), in distinguishing i) geometric analysis, ii) kinematic analysis, and iii) dynamic analysis. The geometric analysis is presented and discussed in sections 3 (folds, domes and basins) and 5 (fractures) of the manuscript. Previous master degree dissertations, thesis and published papers also include geometric analysis for fractures (joints and faults), which are summarized in section 2 (Figure 2), due to the number of pages of the manuscript. The kinematic analysis (paleostress inversion) is developed in section 4 of the manuscript. Section 5 reconciles the geometric and kinematic analyses for fractures. The dynamic analysis of the deformation is made in section 6 of the manuscript. It integrates geometric and kinematic analyses for both folds and fractures, in order to define the deformational regime, the structural relationships between folding and fracturing, and, finally, stress drop and tensor permutation.

Why the manuscript do not deal with Paraná Basin tectonics? The authors consider important to note that Paraná Basin has more than 1.500.000 km2 in area, ∼1.200.000

SED
7, C677–C695, 2015

km2 of which (∼80%) exposes Serra Geral Fm. (Paraná Etendeka Flood Basalts). Most of the territory is mapped to 1/1.000.000 scale, except for some small areas. Taking these aspects into account, the Referee will easily realize that any new detailed mapped area, or even transects, brings more geological data to be evaluated, new stratigraphic and/or tectonic models to be discussed. The authors have been mapping (> 1/200.000 scale) some areas of the Serra Geral Fm., its sandstone intertraps, and the lower contact with Botucatu Fm. since 1989. The master degree dissertations and thesis can be accessed at: http://www.lume.ufrgs.br/ That's why authors do not produced a manuscript dealing with Paraná Basin tectonics. The authors consider that understanding the "fossil" deformational structures (they are Jurassic-Cretaceous in age) will contribute to develop a better tectonic scenario for the Paraná Basin, even it seems a straightforward application. But, there still are some works to be done in order to reach this tectonic scenario. The deformational structures developed in the upper Paraná Basin sequence are the effect (results) of stress state regime (cause) during Jurassic-Cretaceous periods. The authors have long been searching for a stress state regime that reconciles regional (far field) and local strain (the observed deformational structures = effects). These introductory remarks are the basis to consider and answer Referee comments in the following items.

2.1 The Introduction does not explain the real geological problem "The Introduction does not explain the real geological problem. The present Introduction reports the list of the previous works. It is not clear how the work by Strieder and co-authors should represent a progress in the knowledge of the tectonic evolution of the Paraná Basin. In general, the Introduction should be rewritten and re-organised." Authors' response: Taking time distance from manuscript organization period, Referee may be partially right. Authors took with extreme care some obligations defined by the SE Journal, and this may have contributed to some important aspects be left implicit in the Introduction. Then, the Introduction was rewritten to emphasize real structural problem and to make clear the contribution on knowledge of the Paraná Basin deformational regime during Jurassic-Cretaceous periods. But, the manuscript is not yet about Paraná Basin tec-

tonics. At least 2 more steps are required to present an adequate tectonic model for upper sequences of Paraná Basin.

2.2 The geological setting "A "Geological Setting" completely lacks. Although some information have been provided within the Introduction, the Authors are forced to provide the geological framework for the Paraná Basin. In particular, the main Mesozoic tectonic stages are welcomed (deformational phases listed in Table 1 are not enough, and they have to be detailed within the text)". Authors' response: The geological setting of the Paraná Basin is explicit (an intracratonic basin), and two widely known reference are addressed for a broad discussion of the Paraná Basin framework. The discussion about the main Mesozoic tectonic stages is maybe best understood as main Mesozoic stratigraphic stages, but, as pointed out in the manuscript, "The regional stratigraphic correlation and facies change for the uppermost sequences in the Paraná Basin (São Bento Group) remain controversial, . . ." To force Authors providing a discussion of the geological framework, or even the controversial Mesozoic tectono-stratigraphic stages for the Paraná Basin will contribute nothing to the scope of the manuscript (structural analysis) and will just take 2-3 pages more (not including a large bibliographic list and maybe some additional figure). And, in this case, it will be in conflict with Authors obligations, as defined by SE Journal. Instead of, Authors refereed papers that first characterized the most important structural elements/features of the Paraná Basin. In the sequence, Authors provided a presentation of papers that developed geometric and/or kinematic analysis, and distinguished the deformational phases in the Jurassic to Cretaceous periods of the Paraná Basin. These aspects are under the scope of the manuscript, and contribute to understand the changes in the paleostress regime during Jurassic-Cretaceous periods of the Paraná Basin. Then, Authors suggests reading the rewritten Introduction taking into account such aspects. Authors believe that such aspects are solved in the rewritten manuscript.

2.3 The methodology paragraph is not well organise "The methodology paragraph (paragraph #2) is not well organised. It mixes methods and a preliminary report of

SED

7, C677–C695, 2015

results. It is not clear which was the rationale used by the Authors (why they focused on the Serra Geral Fm; which is the main goal of the structural analysis; : : :). Some analytical parts of this paragraph can be moved in an Appendix"

Authors' response i): It is not clear which was the rationale used by the Authors. The rationale used by the Authors was explicitly declared: i) the most important structural elements measured in fieldworks for fault-slip inversion, and ii) the mathematical technique applied for kinematic analysis. In this way, . . . (see next item)

Authors' response ii): Fieldwork methods for brittle structures (Section 2.1). This section does not mix methods and preliminary report of results. But, in fact, it mixes methods with examples of structural elements recovered in different fieldwork stages. E.g.: Figure 2 shows some field examples of fracture patterns in the Serra Geral Fm. volcanic rocks, that leads to elaboration of diagrams for fracture patterns recognition in fieldworks (Figure 3) based on synthetic and antithetic Riedel shear fractures and joint. Figure 4 shows example of striae and steps used to define the sense of movement for faults. Then, attention was paid to fault splay (geometry and symmetry of the splaying Riedel fractures: synthetic and antithetic ones), as also as the type of the striae (it is to be noted that just the clearly defined ones were measured). Authors' response iii): Methods for evaluation of deformational phases in the Serra Geral Fm (Section 2.2). It is well known that there exist a multitude of paleostress inversion methods and also different techniques for discriminating deformational phases based on brittle structures. This section characterizes the applied techniques/methods and shows that such results were confronted with previously results using graphical methods and geometry analysis of field fault-slip data. Authors re-written paragraphs of this Section to make it concise, according the Referee suggestions.

Authors' response iv): why they focused on the Serra Geral Fm. The reasons are: i) the Botucatu and Serra Geral formations (São Bento Group) covers more than 80% of the Paraná Basin; ii) the volcanic rocks best preserve striae, rather than sandstones (it usually shows ambiguous sense of movement due to granulometry and weathering);

SED
7, C677–C695, 2015

iii) Serra Geral Fm. volcanics (Paraná-Etendeka Flood Basalts) deformation may be related to Gondwana rupture. Authors' response iv): which is the main goal of the structural analysis. The main goal of the manuscript was to define the bi-directional stress state for the Jurassic to Creataceous periods of the Paraná Basin, and the stress/strain partition conditions that led to development of a local scale strike-slip stress state.

2.4 Data presentation is elusive "Data presentation is elusive. Deformation structures are not described in detail. The Authors mainly focused on the kinematic and geometric parameters of these structures, although some representations (the π diagram, the balanced cross-section) are questionable (see my comments in the attached ïňĄle)" Authors' response: Authors did not realize what Referee exactly means. The data presentation (π and β diagrams, rose diagrams, field photographs of main structures, maps, and so on) follows all rules on structural geology data presentation and description, as also as classical convention for representation, what make diagrams and maps promptly read. Stereograms are simplified, in sense that they include one structural feature. The description of the deformational structures is fully presented in sections 3 (folds, domes and basins) and 5 (fractures) of the manuscript. When necessary for geometric, kinematic and/or dynamic analysis, the deformational structures description is complemented in sections 4 and 6. Authors introduced some legends in figures or are described in their captions, to make them even more clear to the reader.

2.5 The discussion of the results is centred on the stress states of the deformation phases "The discussion of the results is centred on the stress states of the deformation phases. Anyway, a tectonic scenario framing the deformational phases (D1 and D2) is essential to me for reinforcing the scientiïňĄc message of this work. In particular, I suggest a tectonic scenario for illustrating the regional and meso-scale, major and minor structures that developed under the reconstructed constrictional deformation condition" Authors' response: it seems that Referee is considering Section 6 (Analysis of the deformational phases), the dynamic analysis of the deformational phases. The aim of Section 6 is exactly integrate geometric and kinematic analyses for both

SED
7, C677–C695, 2015

folds and fractures, in order to define the deformational regime, the structural relationships between folding and fracturing, and, finally, stress drop and tensor permutation. Then, Section 6 was renamed to “Stress/strain regime analysis of the deformational phases”, and sub-sections were defined in order the reader can follow the analyses. It is common practice to follow directly from kinematic analysis to tectonic hypothesis. But, Authors consider that at least 2 more steps are necessary to present an adequate tectonic scenario for the Jurassic-Cretaceous period of the Paraná Basin. And, Authors are engaged in data analysis, modelling and some other activities to present such forward results. Authors think that Figures 18 and 19+7E can provide a good illustration of a tectonic scenario emerging from the results presented in this manuscript. These figures also relates major and minor structures developed under the defined constrictional stress/strain regime. Authors sincerely apologize for the changed in Figure 18 (Figure 17 was repeated), which could have contributed to Referee comments and suggestions.

2.6 Conclusion “The Conclusion is not at the point and does not explain the real novelty from this work” Authors’ response: Authors rephrased some sentences, and reorganized other ones to emphasize those findings (novelties) and to make them clearer to the reader.

2.7 Some figures “Some ïňĄgures should be improved (see the attached ïňĄle) (Fig. 18 is wrong, I suppose)” Authors’ response i): Authors highlighted, in Figure 5, the location of detail map presented in Figure 7, in order the reader can easily correlate regional and local geometry of folds and domes. Authors’ response ii): Unfortunately, the figure 17 was repeated as figure 18. The figure was changed to be the correct one. Authors apologize, and can understand some questions rose in supplementary notes by the Referee during Section 6 evaluation.

3 Author’s changes in manuscript Authors’ evaluation of notes directly made in supplementary file. - Title (p1263): Capital letter introduced - Abstract (p1263, lines 4-5): removed. Abstract re-phrased. - Introduction (p1264, line 20, to p1267, line 13): the

SED
7, C677–C695, 2015

Introduction was re-wrote considering the previous discussion (sections 2.1 and 2.2 of this Interactive reply).

- Fieldwork and structural analysis methods: some re-phrased and re-organized sentences considering the previous discussion (section 2.3 of this Interactive reply) > p1267, lines 15-20: re-phrased > p1268, lines 2-24: re-phrased and re-organized sentences. Some sentences were introduced according the Referee suggestions. > p1269, line 6-7: removed > p1269, line 8-29: some sentences were removed according the Referee suggestion (direct reference to original papers), while some others were re-phrased to emphasize the methodological aspects.

- Regional structural features in the ... (Section 3): some sentences re-phrasing according Referee suggestion > p1270, line 12: detail was introduced in figure 5, and also a note to refer detailed map on figure 7. > p1270, line 17-18: the criteria was orientation of the major and minor axes. Examination of reported domes (references in the manuscript) shows it works, the directions are compatible with regional flexures and folds, and with stress/strain main axis. > p1270, line 28: the notation for structural data. The used notation is the classical English Right Hand Rule (RHR). Figures 2 and 4 show some field observed structures and their orientations using RHR.

- Paleostress tensors in the ... (Section 4): some sentences re-phrasing according the Referee suggestion > p1272, lines 18-25: moved to Introduction and Discussion, according the Referee suggestion > p1274, lines 16-19: see p1282, lines 9-20 > p1275, lines 3-4: see p1281, lines 22-27 > p1276, lines 11-12: classical Riedel shear criteria include geometry, angular difference and sense of movement. It is not necessary to specify, since Riedel shear criteria is declared, and field observations included such evaluation according defined in Section 2 (Figure 2 and 3). > p1276, lines 23-25: by 'superposed', Authors mean that NE-SW cut across N-S, and there was offset perpendicular to NE-SW walls (superposed d.b.). There is no shear offset (displacement), which was observed only in shear deformation bands. Authors just care using words that could be understood (or imply) as shear movement. > p1277, lines 1-2: No, it is not

SED
7, C677–C695, 2015

hydrothermal breccia. See Hancock (1985) for definition and discussion on extensional and hybrid joints.

- Section Title: p1277, line 3: the section was renamed to “Stress/strain regime analysis of deformational phases” > Footnote on p1277: Referee suggested to insert a sub-section to present a tectonic scenario for the Paraná Basin. Authors reinforce that such inclusion will change de focus of the manuscript, will expand it to 50-60 pages or more, and that data treatment and processing are not yet ready. However, Authors consider the Section 6 can be sub-divided to make clear each proposition. Authors also inserted a sub-section titled “Time constraint for deformation”, and this section took 1 $\frac{1}{2}$ pages and some concise references.

- Conclusion (p1282, line 21): Authors simplified and re-organized Conclusion section according the Referee suggestions. > p1282, line 22: removed

- Figure 4: scale introduced

- Figure 5: A and B distinguished; legend for stereogram introduced; location of figure 7 inserted for detail; Figure 5 was prepared to occupy a full A4 page, then it enable enlargement to see details as Referee suggest.

- Figure 6: Referee must consider Figure 5 (a simplification of South America Geological Map). The southwestern and northeastern limits of cross-section are on the border of the Paraná Basin. Position of the Ponta Grossa Dyke Swarm was introduced in the figure.

- Figure 7: legend for stereograms introduced; Figure 7 was prepared to occupy a full A4 page, then it enable enlargement to see details as Referee suggest. “π diagrams is usually used for cylindrical folds. In legend of Figure 7A, these folds are non-cylindrical”. Sure, it is right! But, if one divide them into N and S, or E and W sectors, cylindrical folds can be approximated and two opposing fold axis obtained; it is clear that these fold axes continuously change their orientation to each other. That

SED
7, C677–C695, 2015

why some stereograms have two best-fit circles and their pole.

- Figures 8 and 9: legend for stereograms introduced in the figure captions.

- Figure caption for 8 and 9: Figure caption states: “Open circles and open squares in the stereograms represent stress direction determined using the Gauss and MSM methods, respectively. The sizes of the open circles and squares relate to the magnitudes of the stress tensors”. It seems clear that there is 2 symbols (circles, and squares), each for a given technique of fault-slip inversion. And, the size of them is related to the magnitude of the stress tensor; then, the biggest (circle, and square) is $\sigma 1$, the intermediate is $\sigma 2$, and the smallest is $\sigma 3$.

- Figure 10 and 13: a textual explanation for symbols was introduced in figure caption.

- Figure 15: a textual explanation for symbols was introduced in the figure caption

- Figure 18: Unfortunately, the figure 17 was wrongly incorporated (repeated) as figure 18. The figure was changed to be the correct one.

- Figure 19: legend for stereograms introduced; labels for 19c were introduced.

Please also note the supplement to this comment:
http://www.solid-earth-discuss.net/7/C677/2015/sed-7-C677-2015-supplement.pdf

---

Interactive comment on Solid Earth Discuss., 7, 1263, 2015.

SED
7, C677–C695, 2015

Interactive Comment

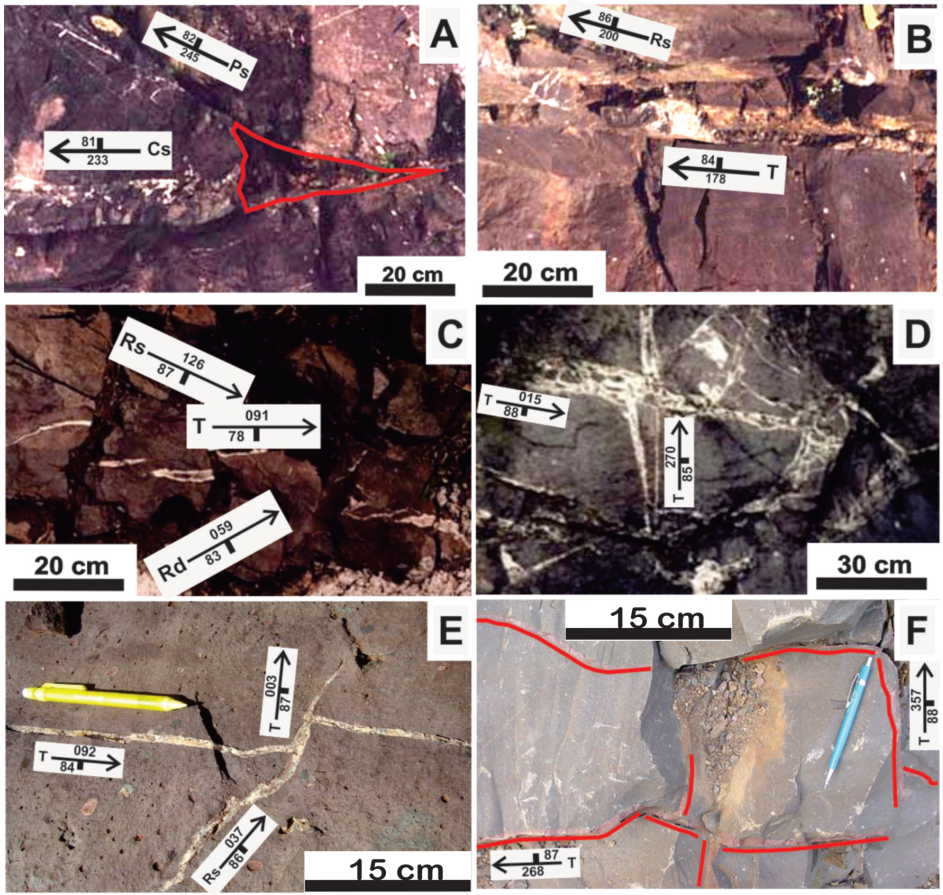

Fig. 1. Figure 2

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

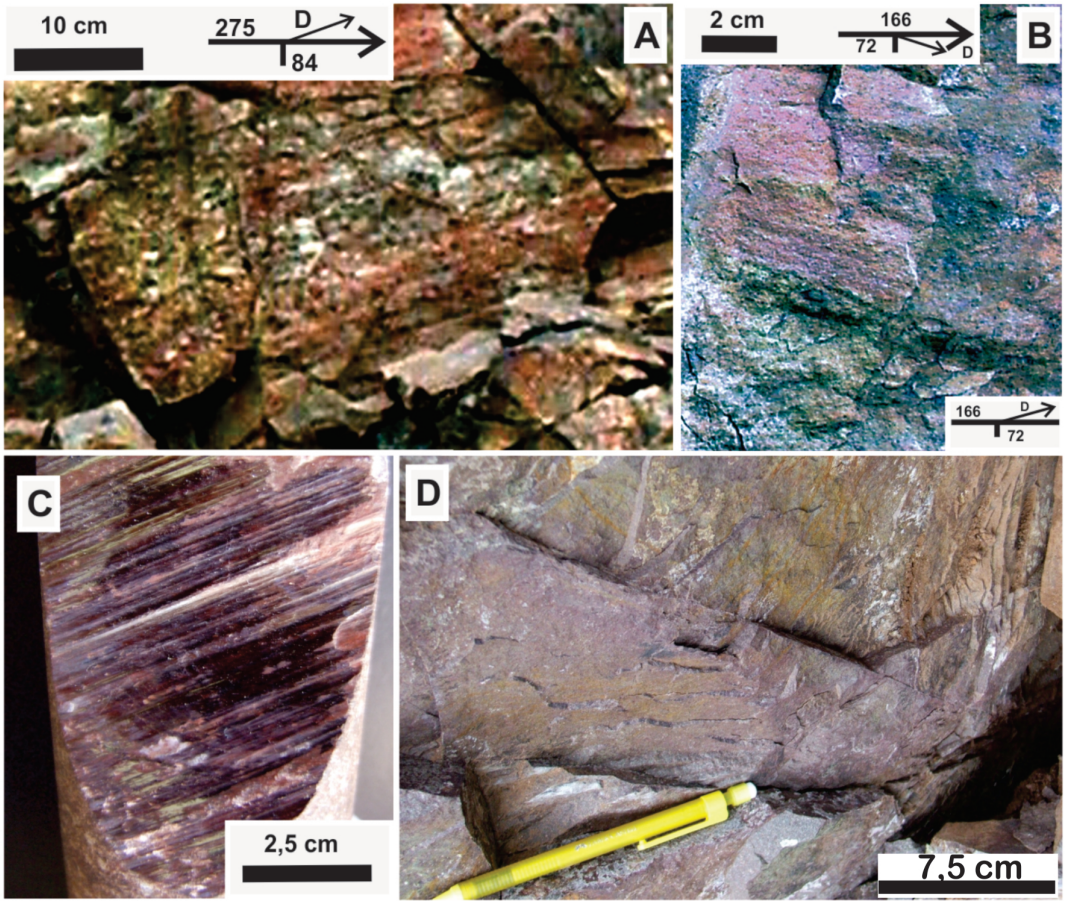

Fig. 2. Figure 4

SED
7, C677–C695, 2015

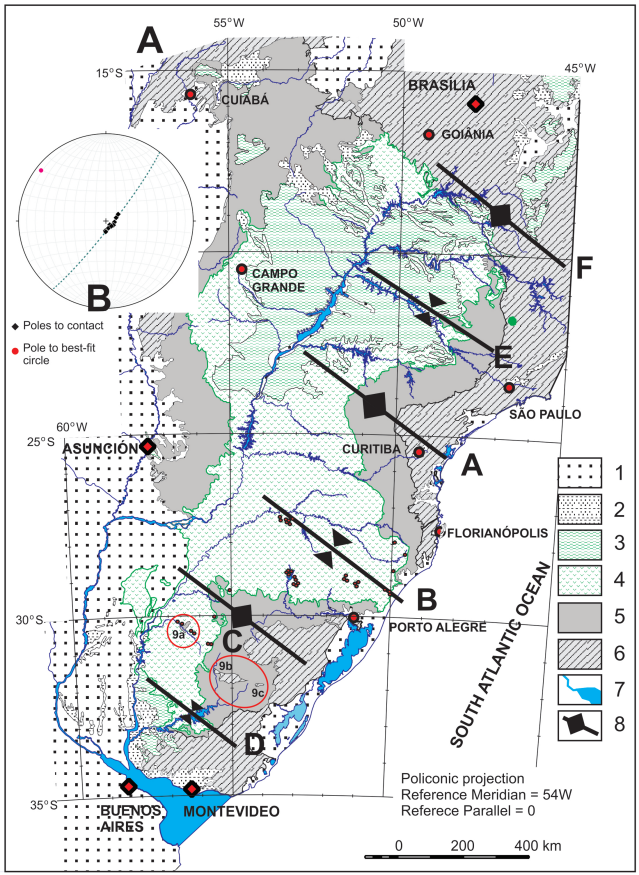

Fig. 3. Figure 5

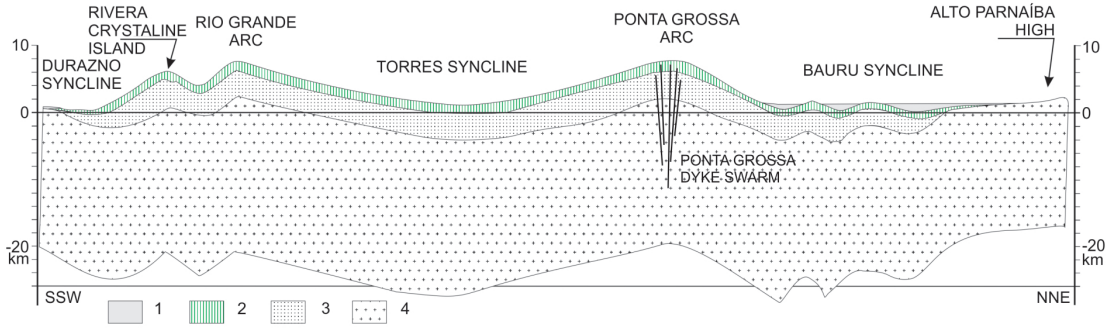

Fig. 4. Figure 6

SED
7, C677–C695, 2015

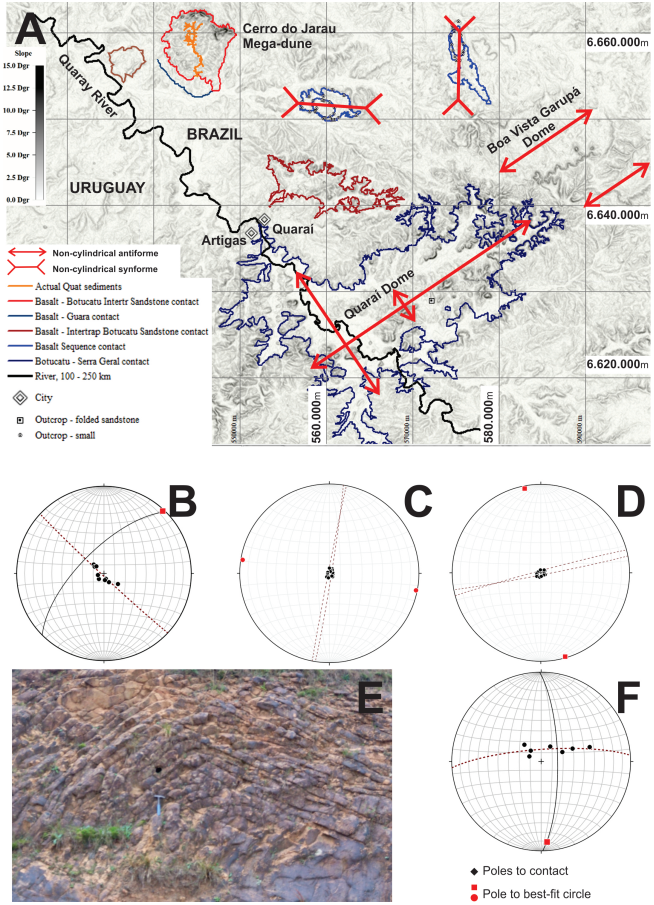

Fig. 5. Figure 7

SED
7, C677–C695, 2015

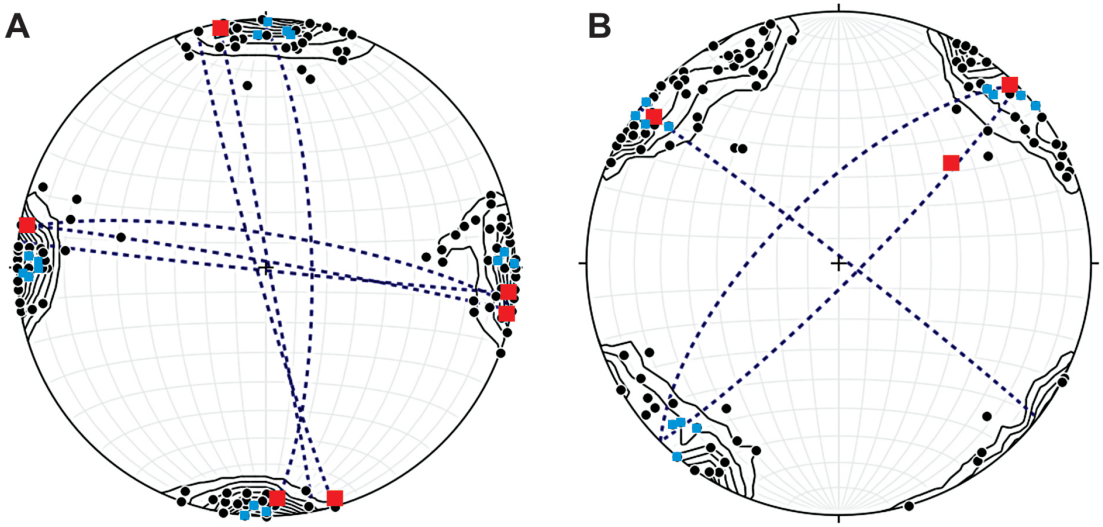

Fig. 6. Figure 15

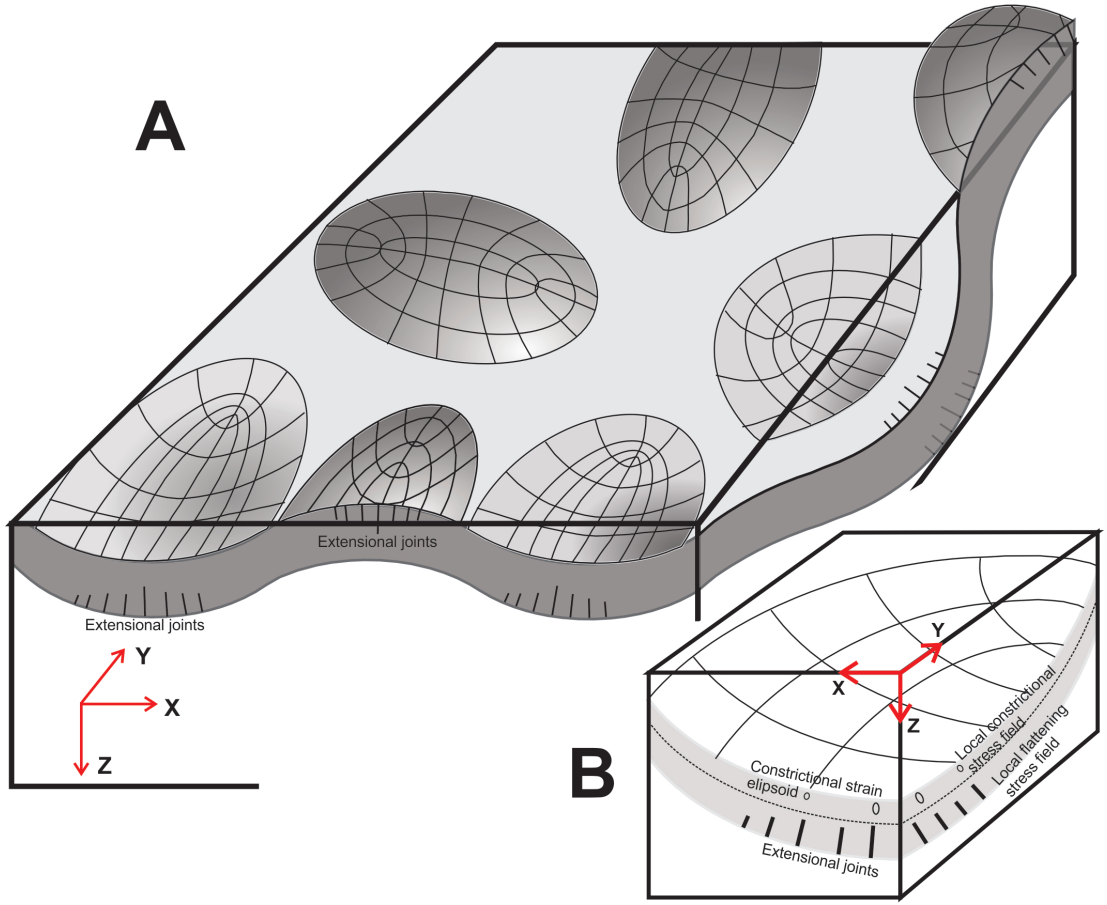

Fig. 7. Figure 18

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

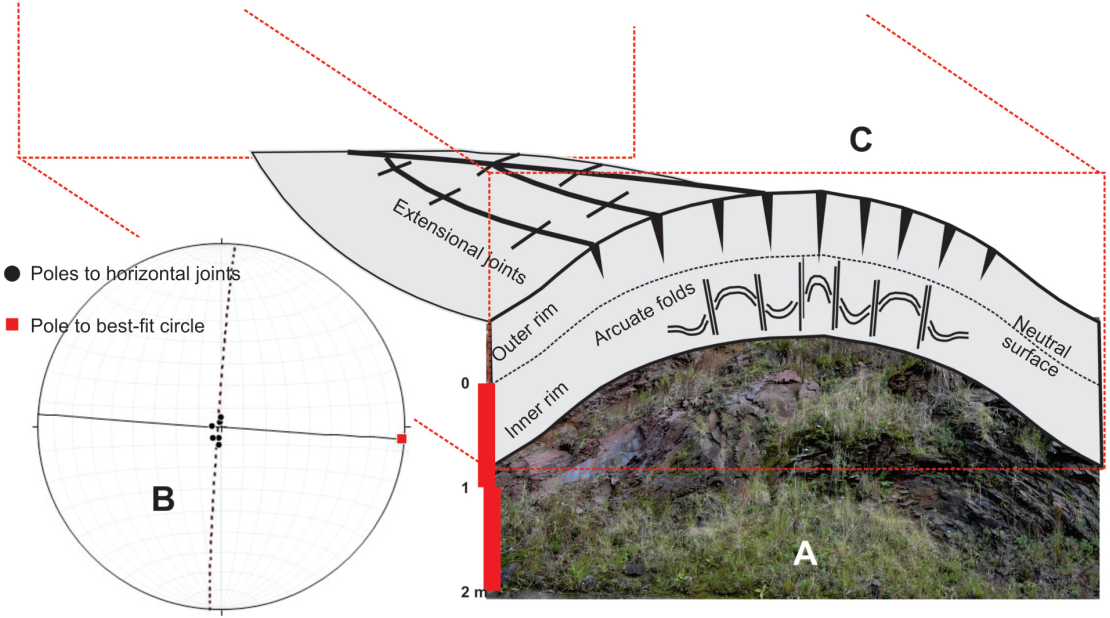

Fig. 8. Figure 19

SED
7, C677–C695, 2015