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Solid Earth Discussions

Interactive comment on "Precambrian faulting episodes and insights into the tectonothermal history of North Australia: Microstructural evidence and K–Ar, ^{40}Ar–^{39}Ar, and Rb–Sr dating of syntectonic illite from the intracratonic Millungera Basin" *by* I. Tonguç Uysal et al.

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Precambrian faulting episodes and insights into the tectonothermal history of North Australia: Microstructural evidence and K–Ar, 40Ar–39Ar, and Rb–Sr dating of syntectonic illite from the intracratonic Millungera Basin.

By Tonguç Uysal, Claudio Delle Piane, Andrew Todd and Horst Zwingmann

General

The manuscript by Uysal et al. provides a large dataset of geochronological (K-Ar, Ar-Ar, Rb-Sr), X-ray diffraction (Kübler and Árkai indexes; illite polytype determinations) and geochemical (trace elements) data from fault and host rocks collected from two boreholes located in the Millungera Basin, Australia. Such an integrated approach aims at determining the previosuly unrecorded Proterozoic tectono-thermal events which affected the Basin. The text is clear and well written, and data are of good quality. Some parts of the text require additional background information and a more focused interpretation of the data.

1) The geological setting is not informative and more background information is required on the region. The authors should briefly describe the main orogenic stages affecting north-central Australia and adjacent basins (e.g. Georgina Basin) since the Musgrave orogeny to let readers understand the interpretation of geochronological data in the framework of regional tectonics. In the discussion section, at least five important tectono-thermal events have been linked to various orogenic phases and magmatic events but no information was given in the geological setting. Furthermore, this section would benefit from a line drawing of the seismic line 07GAIG1 or from borehole stratigraphy (at least for the collected sandstone intervals).

2) Samples from your study have been collected from thrust faults at the margin of the Millungera Basin suggesting basin inversion during the Alice Springs orogeny (400-350 Ma). Why K-Ar and Ar-Ar dating did not record the mid Paleozoic Alice Springs orogeny? Why don't you have neoformation of synkinematic illite during that thermo-tectonic event? May this depend on depth of deformation that may be different between thrust and extensional tectonics? Or did the absence of circulating fluids during faulting affect illite formation? A more detailed discussion on this topic is needed.

3) Kübler (KI) and Árkai (AI) indexes have not significantly discussed in the text and a comparison of ages vs. illite polytypism or age vs Kübler and Árkai indexes is lacking.

The discussion section would benefit from such a comparison. In some cases, Kübler index values indicate diagenetic conditions but most of the illites are 2M1 crystals. This is not very likely and needs a comment. Additionally, KI values from DOB borehole indicate highly variable temperature conditions from early diagenesis (KI=1.0 and T about 100°C) to epizone (KI=0.21; T>300°C) in a very short interval of depths or for different grain size fractions in the same sample (e.g„ dob-389). Authors should provide a geological explanation for such difference in temperature. Alternatively, do KI data record the maximum temperature conditions during faulting or hydrothermal activity, or they provide, in this case, misleading interpretation for very low grade metamorphic zonation? Are KI data reflecting a mixing of authigenic and detrital illite/muscovite populations? It would be also useful to introduce the boundary limits of very low grade metamorphic zones (Diagenesis-anchizone, anchizone-epizone) as calculated by Kübler and Árkai indexes in the CIS scale in the "XRD and SEM clay mineral analysis" section.

4) It is not clear to me whether the X-ray diffraction patterns of oriented mounts in the supplementary material are air-dried or ethylene-glycol solvated tracings and the reason why just one tracing is shown. In my experience both air-dried or ethylene-glycol solvated patterns should be provided to see peak shape variations due to mixed layering, to the occurence of other 10-Å phases (paragonite, phengite, muscovite) that may broaden the 001 illite peak and affect KI measurements. I suggest to draw a figure with a selection of air-dried and ethylene glycol-solvated X-ray patterns for various grain size fractions and move it to the main text. Such a figure could show the deconvolution process used to determine KI and AI measurements. More details on instrumental setting, step size, tube radiation (CuKα, CoKα) should be added in the supplementary material (figure caption or above the X-ray patterns).

Technical points

1) The term "crystallinity" should be avoided throughout the text because it is qualitative and depends on the type of order, the dimensional nature of periodicity and the

technique involved in its measurement. For phyllosilicates and clay minerals, which are low-symmetry minerals with strongly anisotropic structures, various chemical compositions and random or ordered mixed layering, the meaning of "crystallinity" is ambiguous. Guggenheim et al. (2002) - clays and clay minerals, 50, 406-409, suggested that the use of a "crystallinity" index should be avoided and have to be referred to the name of the author who originally described the parameter (e.g., Kübler index for illite FWHM determinations, Árkai index for chlorite FWHM measurements). Please modify the text accordingly.

2) Analytical procedure for performing Kübler (KI) and Árkai (AI) index measurements should be given as many variables influence KI and AI determinations such as sample preparation, instrumental conditions, and the presence of other micaceous minerals in the samples.

a. Background information for slide preparation, cation saturation and density of oriented mounts should be provided b. Have the Kübler and Árkai indexes been calculated from air-dried or glycolated samples? c. How did you perform Kübler and Árkai index determinations? Has the full width at half maximum height been calculated by a deconvolution method, from raw tracing or after background subtraction? d. Please provide standard deviation for your data. e. Authors should provide the "raw data" as measured half-height peak widths as measured in their lab as well as the "calibrated" half-height peak widths as obtained using their own calibration curve. see Kisch et al. (2004) – schweizerische Mineralogische und Petrographische Mitteilungen 84, 323-331 f. Please provide the linear regression equation used for calibrating Kübler index values against the CIS scale. Kisch et al. (2004) recommend reporting the calibration regressions used and the uncalibrated data in all papers reporting on the KI.

2) Mineral abbreviations should follow recommendations by the IUGS Subcommission on the Systematics of Magmatic and Metamorphic Rocks. At the moment Acronyms used for minerals are not appropriate. For instance Kaolinite should be abbreviated in Kln, illite in Ill etc. For a complete list of mineral abbreviations see:

Kretz, R. (1983): Symbols for rock-forming minerals. Am. Mineral., 68, 277 - 279. Mandarino, J.A. (1999): Fleischer's Glossary of Mineral Species 1999. Eighth Edition, 1999. The Mineralogical Record Inc., Tucson, Arizona, USA. Mandarino, J.A. & Back, M.E. (2004): Fleischer's Glossary of Mineral Species 2004. Ninth Edition, 2004. The Mineralogical Record Inc., Tucson, Arizona, USA.

Line numbered comments (minor points)

Line 34 or Line 39 – I suggest to add a recent paper concerning K-Ar dating and illite polytypism of clay gouges from two major orogen scale, long lived faults in northern Iberia useful for understanding the key thermotectonic stages of intraplate brittle deformation. Aldega, et al. (2019). Unraveling multiple thermo-tectonic events accommodated by crustal-scale faults in northern Iberia, Spain: Insights from K-Ar dating of clay gouges. Tectonics, 38 (10), 3629-3651. Line 61 – please provide reference (e.g., Balsamo et al. 2014 - The signature and mechanics of earthquake ruptures along shallow creeping faults in poorly lithified sediments. Geology, 42, 435-438. Line 65 – replace "2M" with "2M1" Line 66 – replace "40Ar-39Ar" with "K-Ar". In addition I would suggest to replace the generic term "clay" with the more appropriate "illite-1M/1Md polytype" Lines 68 and 71– replace "2M" with "2M1" Line 81 – The Carpentaria basin is Cenozoic in age in Figure 1 whereas a Jurassic-Cretaceous age is reported in the text. Please correct Line 136 – I would replace "grade of diagenesis" with "anchizone" as Kübler Index values were originally used for determination of the anchizone. In diagenetic samples Kubler index measurements may be affected by mixed layering and KI values may provide misleading interpretations for very low grade metamorphic zonation (see Aldega et al., 2007 – Clays and Clay minerals 55, No. 5, 504–518.) Line 147- "polarizing microscope" is repeated twice. Line 212 – delete "were used as the calibration standard" Line 258 – delete "and" Line 263 – I would replace "clasts of phyllosilicates" with "phyllosilicate minerals". It is unclear from the SEM picture if they are really clasts or small crystals of phyllosilicate minerals Line 279 to 284. I suggest to briefly describe differences or similarities between illite crystallinity data from differ-

ent grain size fractions (e.g. <2μm and >2 μm) for detecting the metamorphic grade. Line 289 and 290- replace "2M" with "2M1" Lines 301-305- I would be more cautios to assign small rounded crystals detected by SEM images to illite-1Md polytype. The same illite polytype can occur in different grain size fractions and reflect different crystallization episodes. Are you sure that those small crystals cannot be higher grade illite crystals (2M1) reduced by cataclasis or a new generation of illite crystals due to multiple faulting episodes? Furthermore I would delete the assumption of the Ostwald ripening process in the result section. Line 310 – replace "high diagenetic" with late diagenetic or deep diagenetic (see Frey and Robinson textbook pag 70 – Low grade metamorphism, Blackwell science, 1999) Line 314 and 315 – dates of 1099.6$\pm$3.0 Ma and 1106.8$\pm$2.5 Ma reported in the text are missing either in table or in figure 6. Please check Line 320 – K-Ar data are not shown in table 3 as reported in the text. Please check Line 336, 339, 345, 354, 359 – replace "fig. 7a" with "fig. 7b" Line 361, 363 - replace "fig. 7b" with "fig. 7a" Line 362 and 363 – age clusters of 995 and 1115 Ma are missing in figure 7a. Please indicate them Line 375 - replace "table 4" with "table 3" Line 424 – I would add after "carbonate dominated sediments" ...."and at different burial or deformation depths" Line 424-431. Foliated cataclasites have been observed at very shallow depths in siliciclastic sediments (<500 m, e.g., Balsamo et al., 2014 - Geology, 42, 435-438) and carbonate rocks (< 2km; e.g., Smeraglia et al., 2016 - Journal of Structural Geology 93, 29-50) as the result of cataclasis, clay smearing and/or pressure solution-precipitation in presence of fluids during deformation. The authors might refer to these two papers as well. Line 442 – provide reference (e.g., Smeraglia et al., 2016 - Journal of Structural Geology 93, 29-50) Line 461-463- the reference provided is quite old. Authors might refer to more recent papers dealing with metasomatic alteration zones in extensional setting (e.g., Rossetti et al., 2011- Geological Magazine 148 (4), 558–579) and geothermal areas (e.g., Maffucci et al., 2016 – Journal of Volcanology and Geothermal Research 328, 84–95) Line 472 and 491- replace "2M" with "2M1" Line 512- replace "high diagenetic" with "deep diagenetic" or "late diagenetic" sensu Merriman and Frey, 1999. Line 570, 576, 580, 588 – In these lines many

toponysm or names (e.g., smoke hill volcanics, Amadeus Basin, Stuart Dyke swarm, Arunta Block) are missing in figures. A more large scale structural map of north central Australia would help readers to follow the discussion section. This map could easily replace the inset in figure 1

Table 1 – please provide the standard deviation for illite and chlorite crystallinity measurements. I would replace “diagenetic” with “diagenesis”, and “2M” with “2M1” Figure 1 – authors should provide the age for the Mount Isa and Etheridge Provinces, Georgina Basins and Canoble depression as readers may be not aware of the age of Proterozoic-Ordovician basins in north-central Australia. Furthermore, I would add a line drawing of the seismic line 07GAIG1 to better follow the geological setting. Figure 3 –kaolinite described in the text is not shown in figure 3 a and b. Please indicate it. Figure 6 – please label with sample names each Ar-Age plot. Figure 7a – the curve of figure 7a shows the probability distribution of K-Ar and Ar-Ar ages. It is unclear to me why some age clusters have not been labelled. At least, age clusters at about 995 Ma and 1115 Ma should be labelled.

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