Thermal influences on Palaeozoic sediments based on illite-crystallinity data
(Section Tarija-San Vicente, Eastern Cordillera, southern Bolivia)

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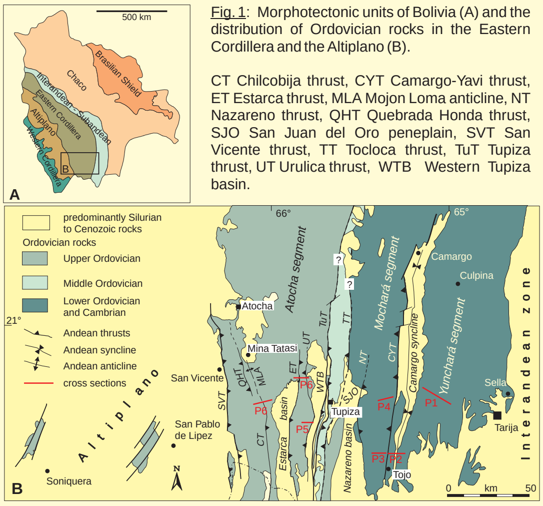

Fig. 1: Morphotectonic units of Bolivia (A) and the distribution of Ordovician rocks in the Eastern Cordillera and the Altiplano (B).

CT Chilcobija thrust, CYT Camargo-Yavi thrust, ET Estarca thrust, MLA Mojon Loma anticline, NT Nazareno thrust, QHT Quebrada Honda thrust, SJO San Juan del Oro peneplain, SVT San Vicente thrust, TT Tocloca thrust, TuT Tupiza thrust, UT Urulica thrust, WTB Western Tupiza basin.

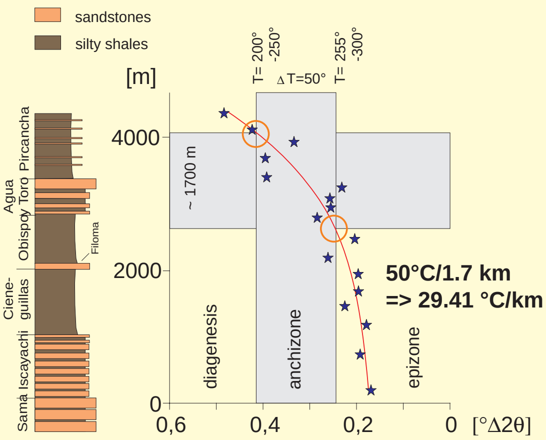

Fig. 2: The illite-crystallinity trend is shown in relation to the Cambro-Ordovician section of the Yunchará segment. The illite-crystallinity values show a regular increase in metamorphism from diagenesis to the epizone. The limiting values for the low- and high-grade boundaries of the anchizone (0.42 and 0.25 °Δ2θ) were taken from Kübler (1984, in Frey, 1987) and are associated to temperatures of 200-250°C and 255-300°C, respectively (Frey, 1987). The difference in temperature of 50°C is related to a 1700 m thick pile of equivalent Ordovician strata. Therefore, a geothermal gradient of ~30°C is estimated. Graptolite reflectance data obtained by Kley & Reinhardt (1994) are accordant to our data set.

Results and discussion

The clay mineral assemblage of the studied siliciclastic sediments are not complex. The dominant whole-rock mineral assemblage is composed of quartz, illite, and chlorite, with minor amounts of kaolinite and feldspar. No minerals such as pyrophyllite or paragonite have been identified. Three stages of illite crystallisation can be distinguished: Diagenetic, very lowgrade, and low grade ones. Areas of high strain in Ordovician strata provide relatively high illite-crystallinity values, while areas of low strain are of lower/transitional values.

Analytically the **Yunchará segment** is characterised by a significant decrease of the illite-crystallinity rate from diagenesis to epizone in a W to E cross section which is correlated to the stratigraphic position of the samples from the Middle Arenigian to the Cambrian (fig. 2).

The **Mochará segment** shows a regular epizonal distribution of the illite-crystallinity values within the stratigraphic level of the Upper Tremadocian to the Middle Arenigian. The Llanvirnian deposits reveal an anchimetamophic overprint.

The **Atocha segment** shows an irregular distribution of the illite-crystallinity values ranging between anchi- and epizone. The samples were derived from stratigraphic levels of the Lower to the Middle Caradocian.

Based on the value trend of the illite crystallinity in combination with the known thicknesses of the Cambrian to the Ordovician strata a geothermal gradient of about 30°/km is deduced at least for the Yunchará segment. The interpretation of the diagenetic and anchi- to epizonal values of the segments may be due to a thick pile of overlying younger rocks. The exposed Pircancha Formation in the Yunchará segment is assumed to have been buried below at least 6 km of younger sediments. However, the overlying rock pile should increase in its thickness to the west on account of the higher illite-crystallinity values in increasingly younger stratigraphic levels. If we consider Palaeozoic rocks for this cover only, we presume a wedge-type sedimentary distribution. An alternative possibility is a locally elevated heatflow due to tectonic events during the Upper Carboniferous or during the Andean cycle.

Introduction

The Eastern Cordillera of southern Bolivia consists mainly of Cambrian to Ordovician rocks locally covered by Cretaceous to Palaeogene and/or Neogene sediments and volcanics. Due to different structural styles it can be subdivided into the Yunchará, Mochará and Atocha segments (Kley et al. 1997, fig. 1B). Concerning the outcropping Palaeozoic rocks, the Yunchará segment in the east and the eastern part of the Mochará segment are composed of Cambrian to Lower Ordovician rocks. Middle Ordovician rocks outcrop in a tectonic wedge in the westernmost part of the Mochará segment, which is bounded by the Tocloca thrust in the east and the Tupiza thrust in the west. The Atocha segment in the west comprises Upper Ordovician rocks, only, in the western part of the Eastern Cordillera. Furthermore, there are smaller outcrops of Upper Ordovician rocks in the eastern part of the Altiplano (fig. 1B).

The age and type of the pre-Andean to Andean tectonic and thermal events are still under discussion. In NW-Argentina a Late Ordovician (Oclóyic) age of deformation has been proposed (Coira et al. 1982, Doherr 1983). In northern Bolivia and southern Peru a Devonian/Carboniferous (Eohercynian/Chanic) age has been proposed (Dalmayrac et al. 1980). Kley and Reinhardt (1994) were the first authors to assume a Hercynian tectonic event based upon geothermometric data-analysis (reflectance of vitrinite and graptolites, fluid inclusions and infrared spectroscopy).

A new approach to evaluate the thermal history of the Eastern Cordillera was made using the illite-crystallinity method. For the first time sections were studied systematically within all three segments. The illite-crystallinity method provides the best results for the determination of prograde thermal influences in the range from diagenesis to low grade metamorphism in rocks without significant mineral assemblages (Weber 1972). Therefore, fine-grained terrigenous rocks of Ordovician age were prepared according to Krumm (1992) and Kisch & Frey (1987) and analyzed according to Kisch (1991) using a Philips PW 1710 X-ray diffractometer with Ni-filtered Cu-Ka radiation, 40 KV, 30 mA, slits 0.5° divergence, 0.2 mm receiving and scanning through 3-32°2θ at a rate of 0.5° 2θ/min. The illite-crystallinity values are based on the Kübler- Index (in Frey 1987).

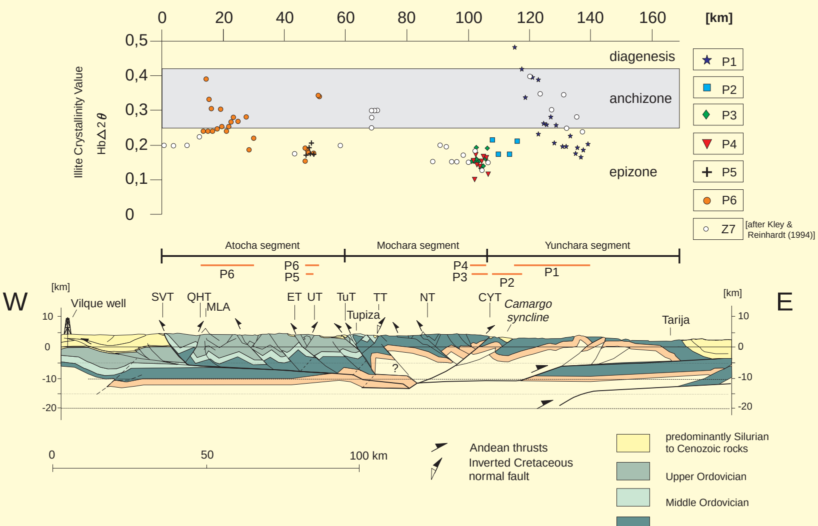

Fig. 3: Tectonic cross section of the eastern Altiplano and the Eastern Cordillera with the different segments and locations of analysed sections indicated. The illite-crystallinity values are plotted in relation to their locality. The distribution of the values reveals the differences in the degree of metamorphism in the different segments. This becomes even more clear in plots of illite-crystallinity values versus stratigraphic position (fig. 4).

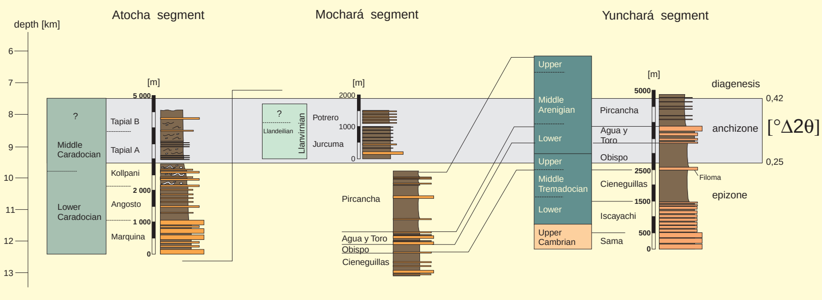

Fig. 4: Illite- crystallinity data in relation to Cambro-Ordovician sequences of the western, central and eastern segments. The data document the anchi- to epizone in the Atocha and Mochará segments, and range between diagenesis and epizone in the Yunchará segment. The age of the equivalent strata increases from the west to the east. The stratigraphical columns were related to the upper boundary of the anchizone and based upon an estimated geothermal gradient of 30°C/km (fig. 2). This implies an overburden of sediments (now removed) ranging between 7.5 - 8 km thickness in the Atocha and Mochará segments to ~7 km in the Yunchará segment. A wedge-type body of overlying sediments thinning to the east is presumed. Legend see fig. 2 and 3.

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