Crustal Shortening Rates in Correlation to Structural Geology in the Sub-Andean Zone of Bolivia

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I. Abstract

The fold and thrust belt of the Bolivian Sub-Andes has been a topic of much discussion and debate for the past twenty years. Varying ideas regarding the Sub-Andean zone (SAZ) structural geology have been published, documenting conflicting ideas on the evolution of this complex region. Variations in balanced cross-sections result in a wide range of shortening estimates, thus highlighting the need for accuracy and precision when constructing balanced cross-sections.

II. Introduction

The structural geology of the SAZ of Bolivia is thought to vary from north to south, and the debate as to why is a geological hot topic. Various geologists have proposed a wide range of catalysts such as lithospheric delamination, lower crustal flow, crustal scale tectonics, and paleotopographical influences to explain the geology of the Central Andes. This poster focuses on the structural and paleotopographical aspects by presenting different balanced cross-sections of the SAZ created by different geologists. I have chosen cross-sections from different authors, grouping them by latitude. Comparing cross-sections from approximately the same location illustrates that predetermined ideology can impact ones interpretation of structure, and how the smallest differences in section can effect crustal shortening estimates.

III. Geologic Background

The Bolivian Andes are located between 14 and 23 degrees South, and are generally divided into five sections: the Western Cordillera (WC), the Altiplano (AP), the Eastern Cordillera (EC), the Interandean Zone*(IAZ), and the Subandean Zone (SAZ) (Fig 1). These regions are grouped by topographic elevation (Fig 2) and, recently, basement structure (Figs. 3 and 4) (McQuarrie 2005, 2006, 2008; J. Kley, 1997). The SAZ of Bolivia is a thin-skinned fold and thrust belt, meaning that all deformation takes place above a main basal detachment overlying un-deformed basement rock. It forms the eastern edge of the Central Andes, and is the region of present day compressional deformation between the Nazca Plate subducting eastward under the South American Plate, which is moving westward. The differences in longitudinal extent of the SAZ are believed to be controlled by a Paleozoic basin (Sheffels, 1995; McQuarrie, 2008; Giraudo, 2001; Baby, 1997; Echevarria, 2001) which inhibits the basal detachment surface from prorogating eastward in some areas of the SAZ. This change in paleotopography is responsible for a noticeable lack of the textbook SAZ structure in a section to the north of the Santa Cruz Bend at the Chapare Basement High (Fig 1). This has caused some to group the SAZ into two separate crescents (Roeder and Chamberlain, 1995) instead of the continuous zone illustrated in Figure 1 b. The topographic layout of the Paleozoic Basin also dictates the shape of the Andes, with the northern section of the orocline exhibiting a width of no more than 550 km, and the southern section reaching 750 km (Kley, 1999). The shape of the orocline is dictated by the extent of the basin, as 'compression across a basin that varies in width produces a thrust belt whose variations in width reflect the basin geometry'(Sheffels, 1988). Sandbox models have been completed to replicate this statement (Baby, 1992).

*Some authors do not include the Interandean zone in their publications (Sheffels, 1995; Giraudo, 2001; Moretti et. al., 1998; Sempere et. al., 1997; Barke and Lamb, 2006; Roeder and Chamberlain, 1995; Watts et. al., 1995).

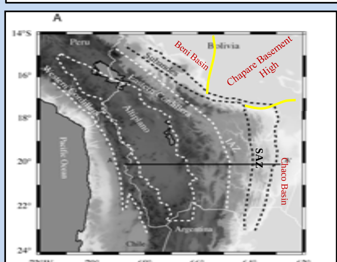


Figure 1-
Topographic map of Bolivia. The five main geologic provinces have been added, as well as the extents of the Paleozoic basin. The Beni Basin narrows northward, while the Chaco Basin extends further westward in to Brazil and Paraguay. (Modified from McQuarrie , 2002)

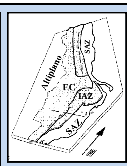


Figure 3 - Illustration of Kley's (1997) interpretation of the basement structure of the Central Andes with geologic divisions. The lack of the SAZ in the Southern Andes has been attributed to the absence of abasement structure for that region.

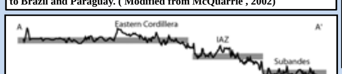


Figure 2-
Topographic cross-section corresponding to A-A' on Figure 1. This section illustrates McQuarrie's (2002) categorization of the Andes based upon topographic elevation.

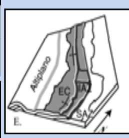
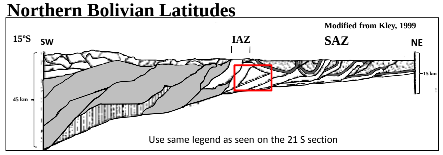


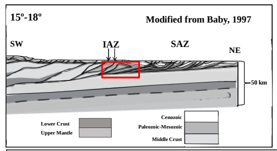
Figure 4-
Illustration of McQuarrie's (2002) structural basement interpretation. Notice the complete continuation of the IAZ to the south, and the exact correlation of basement megathrusts and topographic elevation of the EC and IAZ.

IV. Discussion

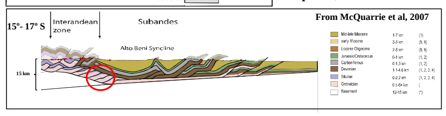
Northern Bolivian Latitudes



Kley, 1999
- **Amount of Shortening**: 74 km
- **Structure**: Basal detachment found in Silurian strata underlies the IAZ and SAZ. The SAZ comprises tertiary sediments filling the Alto Beni Basin, and three main thrusts reaching the surface. The IAZ is comprised of Silurian to Devonian strata, with little folding and stacked duplexes. Note the triangle zone highlighted.
- **Basement Structure**: Independent stacked basement thrusts.
- **Problems**: Defining ages of strata with the terms Paleozoic, Mesozoic, Upper and Lower Crust is quite blanketing, allowing room for possible major discrepancies in interpretation of basement structure.

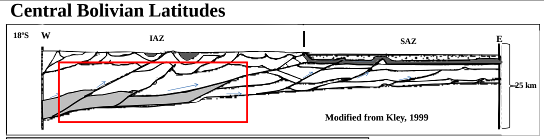


Baby, 1997
- **Amount of Shortening**: 74 km
- **Structure:** Large scale thrust sheets and broad synclines overlying a basal detachment in Ordovician strata.
- **Basement Structure**: Large basement duplexes consisting of middle and lower crust.
- **Problems**: Once again, general terms are used in the description of stratigraphic layers. Also, the triangle zone appears here, indicating that Kley's cross-section may be strongly based on the work of Baby. While Baby interprets this triangle zone to be present, McQuarrie shows this same area to contain several duplexes, structures much more likely to occur.

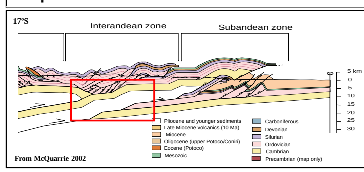


McQuarrie et al., 2007
- **Amount of Shortening**: 66 km
- **Structure**: Large wavelength synclinal basins separated by narrow zones of thrust faulted anticlines. Tertiary basin fill is segmented by a fault propagation anticline of Cretaceous rocks. Three thrust faults carry Devonian rocks upwards from a basal detachment in Ordovician strata
- **Basement Structure**: Large stacked basement megathrust of nearly equal thickness.

Central Bolivian Latitudes

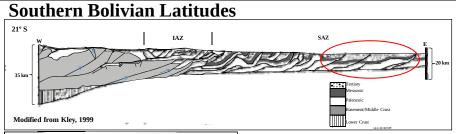


Kley, 1999
- **Amount of Shortening**: 90 km, shorter cross-section length.
- **Structure**: The IAZ is comprised of Paleozoic through Mesozoic strata, segmented by large thrusts and fault propagation anticlines. The SAZ consists of Paleozoic through Tertiary rocks, with fault propagation folding among 3 thrusts.
- **Basement structure**: Stacked independent thrusts.
- **Problems**: Lack of deconstruction in literature allows for speculation in balancing.

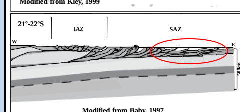


McQuarrie 2002
- **Amount of Shortening**: 72 km, shorter cross-section length.
- **Structure**: The IAZ shows duplexing in Ordovician rocks overlaying a large basement sheet. The SAZ shows deformation of Ordovician through Miocene aged rocks, with Mesozoic rocks lying disconformably over Ordovician in the east. Three major thrusts segregate narrow propagation folds.
- **Basement Structure**: Major flat basement thrust (highlighted).

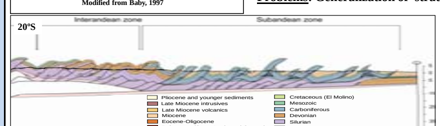
Southern Bolivian Latitudes



Kley, 1999
- **Amount of Shortening**: 79 km
- **Structure**: Several smaller, tightly packed thrusts and backthrusts in the IAZ and western SAZ and three large thrusts segregating strata in the eastern SAZ (highlighted).
- **Basement Structure**: Large individual thrust sheets.
- **Problems**: Generalization of strata dating.



Baby, 1997
- **Amount of Shortening**: 86 km
- **Structure**: Fault propagation folds, fault bend folds, and passive roof duplexes overlying a main detachment in Silurian dark shales. This detachment is covered by 2000m of Paleozoic and Mesozoic sandstones.
- **Basement Structure**: Large thrust sheets of varying thickness.
- **Problems**: Generalization of strata dating.



McQuarrie, 2002
- **Amount of Shortening**: 67 km
- **Structure**: Several imbricate duplexes in Silurian rocks, broad synclines. Basal detachment in Ordovician shale shallows in the IAZ.
- **Basement Structure**: One large, flat Megathrust sheet.
- **Problems**: McQuarrie reassesses her hypothesis of this basement structure in her 2007 publication.

V. Conclusion

Although the amounts of crustal shortening vary by section, the differences are small. This indicates that small discrepancies in stru interpretation will slightly impact shortening estimates. Although McQuarrie's estimates are smaller than Key and Baby's, her data is substantiated in her retrodeformations. Some of the trends in short that are expected are indeed present, with highest amounts seen in t central portion of the orocline. However, one would expect to see hig amounts in the north as compared to the south. This would reflect a structural response to the Paleozoic Basin which is more expansive south, allowing the basal detachment surface to propagate further eastward, accommodating compression, and reducing the need for additional shortening. Therefore, additional research is required to understand this data.

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