GEOMORPHIC SIGNATURE OF QUATERNARY DEFORMATION AND STRATEGIES FOR REGIONAL NEOTECTONIC MAPPING IN ARGENTINA

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Summary

Some data and problems are here analyzed, concerning the current state of knowledge of the neotectonics of Argentina as well as some thoughts for obtaining new information, after the compilation and interpretations of the "Map and Data Base of Quaternary Faults and Folds of Argentina". Specific examples are discussed in order to show that in many cases geomorphic signature is not a reliable criteria for characterizing times and rates of recent deformation. The usefulness of the term "active fault" and activity-related fault classifications are also discussed.

Introduction

The distribution and characteristics of Quaternary tectonic deformation in Argentina is strongly influenced by the subduction geometry of the Nazca plate and by plate interaction in the southernmost Patagonian Andes. More than 90% of the structures compiled within the framework of the "World Map of Major Active Faults" (ILP Task Group II-2) are above the flat-lying portion of the subducted plate between 27° S and 33° S (Fig. 1). Blind and emergent thrusts characterize recent and ongoing tectonic processes at the Andean orogenic front. Quaternary cratonward deformation is expressed by reverse faults that bound the asymmetric foreland uplifts of the Sierras Pampeanas.

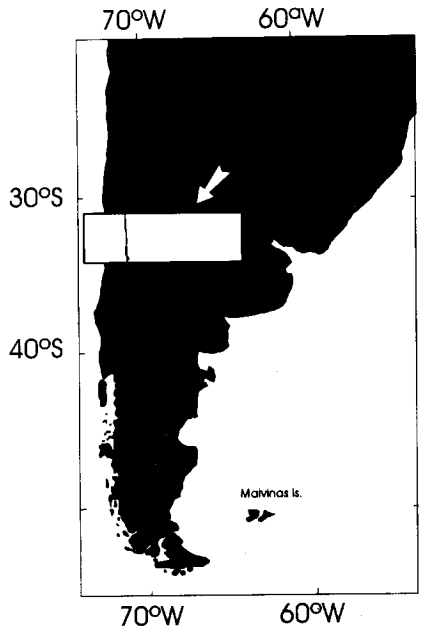

Figure 1
Location of the analyzed area

The main morphotectonic settings in this region are comprised of: a) rectilinear scarps related to a conspicuous wrench fault (El Tigre Fault, Western Precordillera), b) distributed reverse faulting along bedding planes (Eastern Precordillera), c) poorly preserved thrust-related scarps (Orogenic Front at Mendoza), d) warping and upbulging with different erosional stages linked to growing anticlines (Andean Foothills) and e) reverse faults scarps related to basement thrusts in the Sierras Pampeanas.

The development of the ILP II-2 Project provided a suitable opportunity for synthesizing the present body of knowledge under common references and for discussing the masterlines of future neotectonic works in Latin America. Conversely, a common data base was developed in order to fit the information profile for the majority of the Quaternary structures.

In Argentina, most of the Quaternary deformation already known is under a recconnaissance stage and an important part of the information comes from remote sensing-based studies with complementary field work. Hence, the recognition of Quaternary deformation strongly relies on terrain analysis and diagnostic tectonic-related morphologies.

Almost all the significant Quaternary structures are developed under compressive tectonic settings, both in thin-skinned and thick-skinned environments that pose particular problems in terms of the relationships between fault activity and geomorphic signatures.

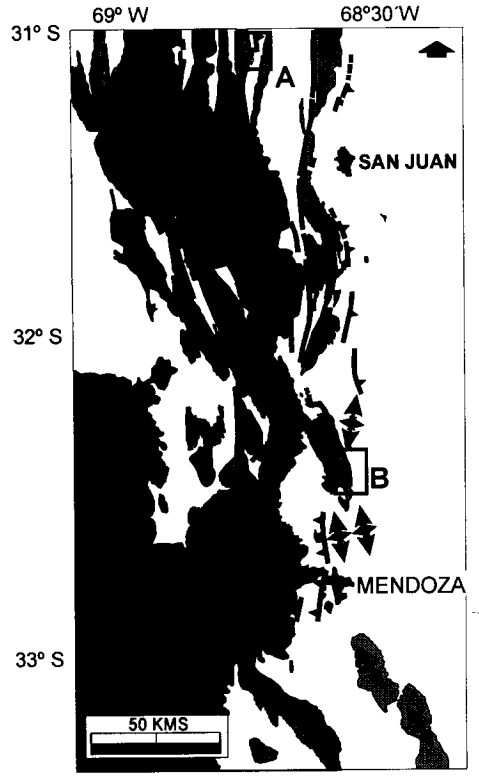

Figure 2
General sketch of main Quaternary faults and folds in the Precordillera area. A. Blanquitos zone, B. Las Peñas zone.

Because Quaternary activity of seismogenic structures is a basic input for regional seismic-hazard characterizations, it is necessary to understand the reliability of terrain analysis diagnosis based on geomorphological constraints. Another issue to analyze is the discrimination of recent deformation based on activity and significance in terms of seismic-hazard assessment. This approach has been encouraged by many federal agencies and policy makers and is commonly used for characterization of dams, nuclear power plants and nuclear waste site characterization. Not to mention that the term "active fault" is a concept well nested in the scientific vocabulary (Machette, 1999).

However, it is understood that "active fault" concept could be misleading, for these reasons:

1. There is no a general agreement about when a fault should be considered "active" and conversely, any definition given is just a convention based mainly on the tectonic setting, the type of study amount and type of data available (Machette, 1999) or the author's conception of the problem.
2. Geologic scenarios of Quaternary deformation in Argentina vary from the seismically active Andean orogenic front (Precordillera and Sierras Subandinas fold and thrust belts) to intraplate faulting in the Sierras Pampeanas, where instrumental seismicity has no an evident correspondence with the main morphotectonic features. Fault recurrence and slip rates are not well established yet for the main potential seismogenic sources in Argentina. Even accepting that recurrence intervals are shorter and slip rates higher at the orogenic front (main parameters for defining a fault as "active"), it is not clear exactly what it means in terms of seismogenic capability of these structures. There are faults in the Sierras Pampeanas with more than 2 m of displacement in the past millenium. These faults should formally be considered as active, even without reliable data on recurrence and slip rate. If such faults have an average recurrence interval of, say, 10.000 years, then they might be considered less hazardous in terms of seismic threat than other structures without coseismic slip during the late Pleistocene-Holocene, whose last movement are recorded as 10.000-20.000 years B.P. This means that where long recurrence intervals prevail, the most "active" structures (i.e. those with Holocene slip documented but very low slip rates) might pose less seismogenic capability that other faults without recorded slip during the late Pleistocene-Holocene (sometimes called "Potentially Active" or "Capable Faults").

Data base and map references for Project II-2 enphasize fault type, geometry and related morphologies and when possible time of last movements (Quaternary, Holocene, Historic) and slip rate information (Trifonov and Machette, 1993), rather than fault activity (i.e., active, potentially active, etc.). It is envisaged that this is a more suitable approach particulary for regions portraying just basic information on recent deformation.

Some examples of Quaternary deformation and geomorphic signature relationships

Blanquitos fault system

The Blanquitos area is located at the active Andean front in the Eastern Precordillera fold and thrust belt at 31°S (Fig. 2), where Quaternary deformation is characterized by rectilinear NNE-trending parallel faults scarps on Quaternary bajadas (Paredes *et al.*, 1997) and other discontinuous fault traces (Fig. 3).

The scarps of the Blanquitos fault system are coincident with

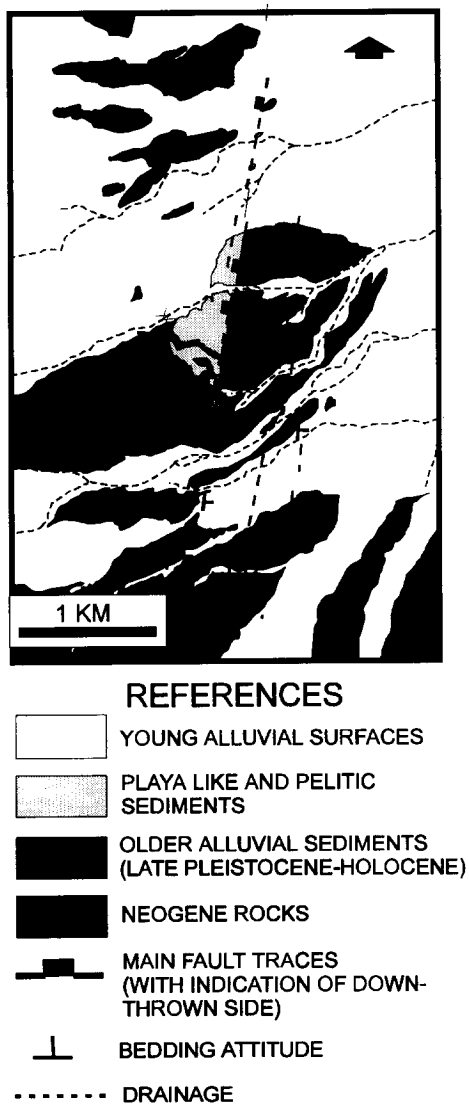

Figure 3
General sketch of the Blanquitos Fault System, showing the distribution of Quaternary faulting affecting the alluvial cover. Adapted from Paredes et al., 1997 and Costa et al., 1999a.

Neogene strata (bedding) surfaces and have been interpreted by Costa *et al.* (1999a) as interbedding faulting. This relation suggests the faults might not be primary rupture surfaces but rather parallel faults merging at depth into a master thrust-fault. If surficial slip during an earthquake is distributed among several parallel fault planes as in this case, then some types of information obtained from each individual fault (i.e. slip per event, rupture length) may lead to an underestimation of the potential related to the master source or main slip/detachment plane, according to commonly used empirical relationships.

Las Peñas thrust

This thrust has concentrated the main slip of the growing Andean orogenic front at northern part of the Mendoza province (Fig. 2) during most of the Quaternary, where highly deformed Neogene clastic rocks are overriding a thick sequence of alluvial-fan deposits (Cortés and Costa, 1996; Costa *et al*, 1999b). The high erosion susceptibility of the hanging wall rocks preserve no fault related morphologies near the thrust trace, instead only smooth hillslopes are seen (Fig. 4). There are no concordant relationships between topographic and structural relief and conversely, the occurrence of obvious Quaternary movements here are hardly imaginable from photogeological analysis. Evidence of Quaternary deformation is only suggested by the 2-5 m-high gentle monocline scarps in alluvium (Fig. 4) which represents solely the latest slip of this important structure.

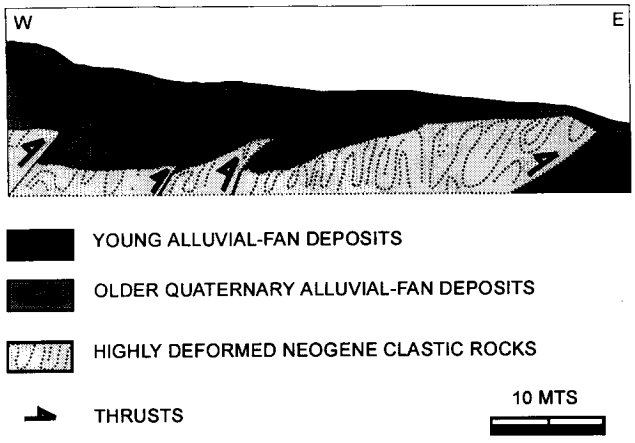

Figure 4
Quaternary structures exposed at Río de Las Peñas with no direct relationships between fault-related morphologies and the Quaternary fault slip. Adapted from Cortés and Costa, 1996 and Costa *et al.*, 1999b.

Sierra Chica fault

This structure is the easternmost Quaternary fault related to the southern Sierras Pampeanas (Fig. 5), a chain of Neogene uplifted blocks from the broken Andean foreland developed above the flat-lying subduction segment of the Nazca Plate beneath South America (27°-33°) (Jordan and Allmendinger, 1986). The Sierra Chica Range is bounded at its western flankhillslope by high- to medium-angle reverse faults which flatten at depth (González Bonorino, 1950; Introcaso et al., 1987; Costa *et al.*, in review). The neotectonic (Pliocene-Pleistocene) front is in agreement with the main hillslope break displaying a mountain scarpment with fault-related morphologies. However, the most recent faulting is located several hundreds meters away from the mountain front, thrusting the crystalline basement with low angle over non-disturbed Quaternary alluvial deposits (Fig. 5). No topographic signal is related to this structure, except for a slight upbulge which could be reasonably interpreted as a non-tectonic feature. Again, morphology can not be used here as a reliable tool for evaluating the significance of recent faulting in terms of location and activity.

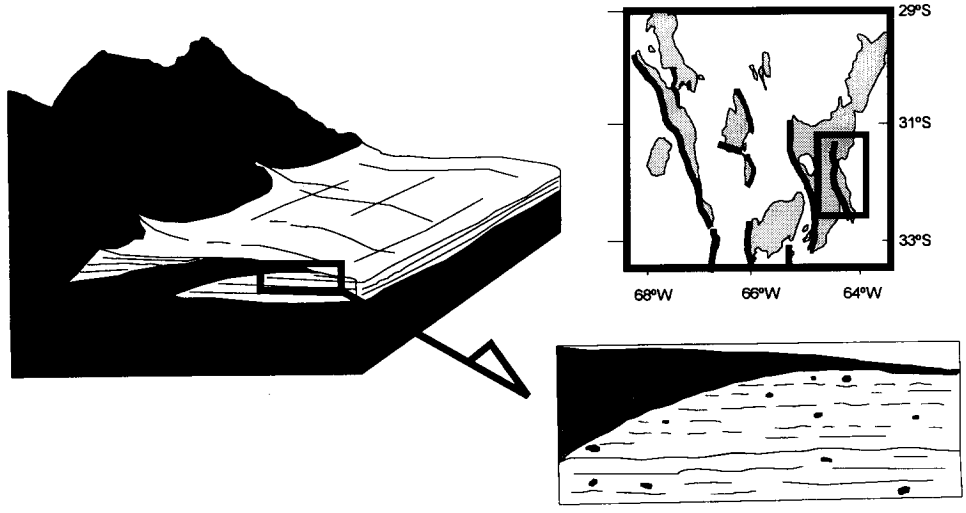

Figure 5
Location of the Sierra Chica fault (pointed out with a quadrangle in the location sketch) and observed style of recent faulting. Crystalline basement in grey. Quaternary coarse alluvial deposits in white.

Conclusions

In characterizing Quaternary tectonic deformation on a regional basis, one has to consider that detailed paleoseismic information is sparse in Argentina. Age constraints for Neogene materials are limited and reliability of data is variable. It is understood that regional-scale mapping strategies should discriminate type and geometry of deformation, occurrence of off-fault phenomena, type of studies (remote sensing-based, general or detailed field studies), and evaluate reliability of data.

In the past, many regional neotectonic studies have characterized type and activity of recent deformations based on their morphological features. Some examples discussed here show that geomorphic expression may seriously mismatch the significance of recent tectonic phenomena in terms of accumulated slip in the Quaternary, slip rate and/or related seismic-hazard threat.

Characterization of Quaternary structures based on previously established categories of fault activity or capability are not considered to be an useful strategy, taking into account the present state of knowledge and the different geologic scenarios of recent deformations. Thus, maps with references based on the time interval of the last recorded fault slip (i.e., faults with Quaternary, Holocene or Historic activity) are considered more objetive because different users can judge their meaning in terms of seismic-hazard.

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