NEOTECTONIC ACTIVITY IN THE NORTHERN SIERRAS PAMPEANAS, ARGENTINA

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Abstract

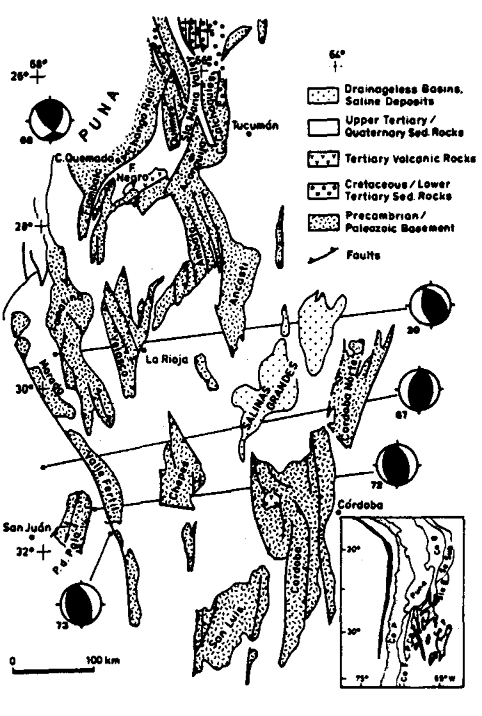
The Argentine Sierras Pampeanas (26° to 33°S) are reverse fault-bounded mountain blocks of Precambrian to Paleozoic basement rocks in the foreland of the central Andes. Uplift in the northernmost Sierras Pampeanas fault blocks of Sierra de Quilmes, Sierra Cumbres Calchaquíes, and Sierra Aconquija started about 7 Ma and became pronounced between 4 and 3.4 Ma. The movements culminated after 2.9 Ma, when the conformable Mio/Pliocene Santa María Group was overthrusted, faulted, and folded in the course of principal basement uplift. These movements created climate and base level conditions that resulted in the formation of five pediment levels in the deformed basin strata between 2.5 and 0.3 Ma. Tectonically induced base level changes in the piedmont resulted in three tectonism-related pediment surfaces between 2.5 and 0.6 Ma, which attest to the neotectonic activity in the Andean foreland. In conjunction with the principal uplift of the adjacent Puna Plateau the nórthernmost Sierras Pampeanas are best explained by E-W compressional stresses superposed on a thinned lithosphere and inherited zones of structural weakness that facilitated uplift.

Introduction

The "thick-skinned" Sierras Pampeanas (26° and 33°S) are characterized by Proterozoic to lower Paleozoic crystalline mountain blocks that were uplifted along high-angle reverse faults during late Cenozoic time (Fig. 1). Separated from each other by tectonic depressions that are filled with Tertiary and Quaternary sediments, the sometimes more than 5000-m-high ranges protrude out of the low-lying Andean foreland (4, 8). The ranges define a 450-km-wide belt of Laramide-type uplifts and are presently under E-W horizontal compression (4). Between 28° and 33°S the location of the ranges correlates well with a flat subduction segment (<10°) of the oceanic Nazca plate. In contrast, the northern Sierras Pampeanas (north of 28°S) occur over a seismic transition zone to a steeper subduction segment, which is located at about 25°S. This transition coincides with a geologic transition into the intra-Andean Puna plateau, an inverted Cretaceous rift (Santa Barbara System, Sta. B.), the Cordillera Oriental (Co. O.), and the "thin-skinned" Sierras Subandinas (Sa. Sub., Fig. 1). The transition to different tectonic provinces suggests a relationship between the angle of subduction and deformational styles in the overriding plate. One of the prime sites to demonstrate the tectonic and geologic history of the Sierras Pampeanas with special emphasis on the young deformation exists in the Santa María Valley in the northern part of the Sierras Pampeanas. Within a distance of 50 km, elevations change from 400 m in Tucumán to 4000-5400 m in the basement blocks that the delimit the approximately 2000-m-high Santa María Valley (Fig. 2).

Geologic setting and stratigraphy of the Santa María Valley

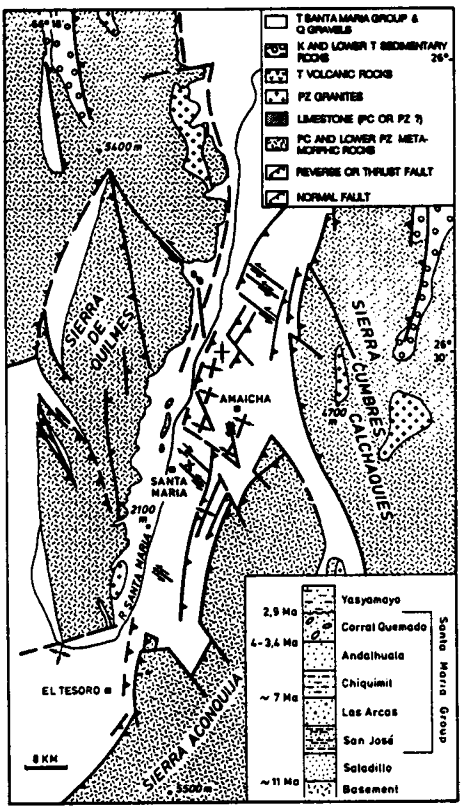
The basement blocks that border the Santa María Valley are the Sierras Aconquija, C. Calchaquíes and Quilmes that mainly consist of schist, gneiss, and migmatites (Fig. 2). In the transition to the other geologic provinces to the north the basement grades into low-grade metamorphic rocks. In the Santa María Valley there are seven Tertiary units overlying crystalline basement and allow to evaluate the Late Cenozoic faulting history. The lowest unit is the 11 m.y. old Saladillo Formation (G. Bossi, oral communication), a fine- to medium-grained sandstone 306 m thick that overlies the Aconquija basement. It possibly correlates with the 10.6 m.y. old El Morterito Fm. that overlies the crystalline basement of Sierra Quilmes on the west. In the Santa María Valley the sedimentary units are a Mio-Pliocene coarsening upward sequence and include the San José, Las Arcas, Chiquimil, Andalhuala, Corral Quemado, and Yasyamayo formations (Fig. 2). Except for the Yasyamayo Fm, these formations are treated here as the Santa María Group (SMG; 1, 8). At the base of the SMG are sand- and siltstones of the marine San José Fm., which contains fossil fish, stromatolites, and foraminifera. It is conformably overlain by brown to dark red sandstones of the undated Las Arcas Fm. These basal units are overlain by medium- to coarse-grained sandstones and sandy conglomerates of the approximately 1800-m-thick Chiquimil and Andalhuala formations, which define an age range between about 7 and 3.4 Ma (8). The strata have westward transport directions and indicate a lowland-type low-energy braided river depositional environment with lithologies related to Sierra Aconquija and Sierra C. Calchaquíes. These sediments are covered by the up to 1000-m-thick Corral Quemado Fm, a medium- to coarse-grained and blocky conglomerate typical of alluvial fans. All sections display westward transport directions and a composition derived from the basement of Sierra C. Calchaquíes and Sierra Aconquija. The uppermost parts of the conglomerate contain a dacitic lense with a fission track age of 2.96 ± 0.57 Ma. In the northern part of the valley this formation is unconformably overlain by the 298-m-thick Yasyamayo Fm that consists of alternating horizons of pelite and gypsum. Other excellent chronostratigraphic reference horizons for the evaluation of neotectonic activity in that region are the erosional remnants of five formerly continuous pediments and their conglomeratic covers that define an age range between 2.5 and ~0.3 Ma. The first 3 pediments are tectonically deformed and are 2.5, 1.2 and >0.6 m.y. old (8).



Generalized geologic map of the Sierras Pampeanas; Sierras Pampeanas stippled (Sa.P.); after (4) and (8)

Neogene and Quaternary Deformation

The presence of marine strata at the base of the SMG indicates that the region of the northern Sierras Pampeanas was still a lowland more recently than 11 Ma. Initial uplift began between 11 and 7 Ma, when the Chiquimil and Andalhuala Formations began to be deposited in front of the uplifting Sierras Aconquija and C. Calchaquíes. The drastic change in sedimentary environments with alluvial-fan deposition between 4 and 3.4 Ma is interpreted with increased tectonic uplift. With pronounced tectonism the influx of the conglomerates could be interpreted either as a function of increased proximity to an already moving thrust sheet or as the beginning of uplift in the thrust sheet, in either case responsible for uplift of the adjacent ranges. In the first alternative the Corral Quemado Formation is a mountain front facies, which appeared at the locus where strata were preserved between 4 and 3.4 Ma. This implies that the Corral Quemado Fm exists in the sub-surface of the migrating basement blocks and that the relief of the ranges cannot be inferred to have changed significantly through time. In such a scenario the uplift during the initial phase before 4-3.4 Ma was of greater magnitude. In this case the tectonism would be explicable with asymmetric basement uplift along a westward migrating thrust front. To date, the lack of exact structural data from the east side of Sierra Aconquija may support such a view. In contrast, bounding faults at the west and east side, and a partially preserved peneplain in Sierra C. Calchaquíes, exclude a westward migrating basement block that created spatially similar facies and migrated across its own basin fill in the final stages of the Santa María depocenter.



Geologic map of the Santa María Valley, after (8)

In any case, the principal tectonic event that deformed the entire Tertiary sequence, and which must have been associated with major uplift in the ranges, is later and took place after 2.97 ± 0.6 Ma (8) .In the course of these movements Sierra Aconquija and Sierra C. Calchaquíes and their adjacent piedmont regions were primarily affected by faults with NNE and NW strikes (Fig. 2). The range-bounding faults involve throws in excess of 7000 m and dip as much as 85°E. Folding is associated with reverse faulting, and in several locations drape folds developed where basement faults lose throw. In general, deformation was characterized by ESE-WNW oriented shortening and vertical extension. Uplift of Sierra de Quilmes was accomplished along NW-SE trending reverse faults within the range (Fig. 2). Faults parallel to the trend of bedrock schistosity indicate predisposition of the basement to rupture and uplift along older structures. Evidence for recurrent tectonic movements postdating the main deformation after 2.9 Ma is abundant in the Santa María Valley. Faults and folds that were active during the Plio-Pleistocene have been reactivated, with an amplification of folds and an increase of dip in strata along faults. The continuation of tectonic movements is well documented by faulted and folded pediments in the piedmont regions and along the moutain-bounding faults. For example, pediment II was once a continuous surface that originated at the C. Calchaquíes mountain front and predates uplift of the asymmetric northermost portion of the Aconquija block. Thrusting and uplift along the Aconquija fault after 1.2 Ma brought the higher-grade metamorphic basement rocks into direct contact with the pediment (8).

The absence of large faults that cut the extensive pediments IV and V (0.6 - 0.3 Ma) does not imply that tectonism has ceased. 2-ka-old fault scarps in floodplain and alluvial-fan sediments attest to active tectonism, and earthquakes in 1906 and 1936 with estimated magnitudes of 6 demonstrate the continuation of tectonic movements to the present day.

Discussion and Conclusions

Range uplifts in the Sierras Pampeanas above the shallow subduction segment show similar chronologic patterns as in the northern part of the province above the transition zone to a steeper segment. Initial uplift in the Sierras Famatina and Velasco is indicated at about 7 Ma, and uplift of the Sierra Morada in the western Sierras Pampeanas occurred after 5.7 Ma (6, 7, 9). Thus, the tectonic history of the late Cenozoic northern

Sierras Pampeanas raises an important question as to whether the ranges are indeed related to processes associated with the subhorizontal subduction of oceanic lithosphere or if perhaps other factors have caused their uplift. For the northern Sierras Pampeanas, shallow subduction is incompatible with the existence of Cenozoic volcanism as far south as 28°S. In contrast, volcanism in the region between 28° and 33°S experienced a progressive decline in activity and migrated east beginning in the Miocene because of the shallowing of the subducting plate segment (5). However, no such clear relationships between shallow subduction and Sierras Pampeanas-style basement uplifts exist in the Andean foreland above the shallow amagmatic subduction segment of Ecuador/Peru between 2° and 15°S, where foreland deformation is limited and appears to be influenced by paleogeographic controls. Basement uplifts occur not only over steep but also over shallow subduction segments (R. Coward, oral communication, 1988; 2). Consequently, plate geometry does not exclusively determine foreland deformational styles, and certain crustal predispositions may be necessary to cause widespread deformation over a shallow subduction zone. In the light of crustal properties and distinct mechanical responses to an overall compressive regime uplift of the central Sierras Pampeanas related to shallow subduction is not at variance with an equal tectonic style within the seismic transition zone, if the similar crustal inheritance of the region is considered. In the transition zone the mountain blocks are structurally and morphologically equivalent to the central Sierras Pampeanas. However, this situation changes gradually in the area of the weaker basement and the Cretaceous rift basins in the Santa Barbara System and disappears farther north (4). An explanation to understanding the northern Sierras Pampeanas uplifts in this context is through a model that takes the close spatial position of the Puna, lithospheric thinning, and the active volcanism of the region into account. In the seismic transition zone the cross-sectional topographic area of the Andes, with mean elevations above 3000 m, increases drastically and signals the southern boundary of the wide Puna/Altiplano plateau. The northern Sierras Pampeanas are transitional to the plateau, and their uplift may have been linked to the processes that caused the final uplift of the plateau. Isacks (3) explains the plateau by a combination of distributed structual shortening and thermal expansion, resulting from a thinned South American lithosphere, which is caused by a broad asthenospheric wedge between a moderately inclined, but not horizontal, subducting plate and the overriding plate. In such a scenario, due to thinning, the strength of the upper plate is low and susceptible to thrusting and long-wavelength thermal uplift. Because of the same type of inherited structures, paleogeography, and lithology, the region of the northern Sierras Pampeanas may thus have reacted to compressive tectonic stresses in a similar manner as equivalent rocks above the region of shallow subduction between 28° and 33°S.

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