DEFORMATION PROCESSES IN THE ANDES
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Thrust tectonic controls on late Tertiary sedimentation pattern in the Salar de Antofalla area, southern Puna (NW Argentina)

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Geological setting

The Salar de Antofalla area is part of the Altiplano-Puna plateau of northwestern Argentina and southwestern Bolivia. Especially the southern Puna is subdivided into numerous endorheic basins. Our study presents a comprehensive view on the basin evolution and its sedimentary strata during the late Cenozoic.

The Salar de Antofalla basin, and the adjacent volcanic belts developed on a continental crust composed of a Precambrian to early Paleozoic high-grade-metamorphic basement, early Paleozoic sedimentary and volcanic rocks (PALMA & IRIGOYEN,1987) as well as Permotriassic and Jurassic sediments (VOSS et al.,1996) (Fig. 1 B).

Andean sedimentary evolution presumably started during the late Eocene. Initial deposits (Quinuas unit, GÖRLER et al., in prep.) consist of sediments of a alluvial plain environment. After SEMPERE (1995) it developed in a broad foreland basin situated east of the late Cretaceous-early Tertiary magmatic arc. A tectonic and sedimentary upheaval during the late Oligocene and early Miocene involved a rapid change from a foreland to an intramontane basin setting. Due to increased tectonic activity during the Pehuenche (18 - 22 Ma), the Quechua (14 - 10 Ma), and the Diaguita phase (4 - 2 Ma) the Andes grew as a mountain belt and the study area became structurally isolated. Intramontaneous sedimentation was restricted to a variety of narrow, mostly N-S trending compressional basins. In the Salar de Antofalla basin itself, sedimentation continued with the Potero Grande (Mid- Miocene) and Juncalito units (Upper Miocene to Pliocene) (GÖRLER et al.,in prep.).

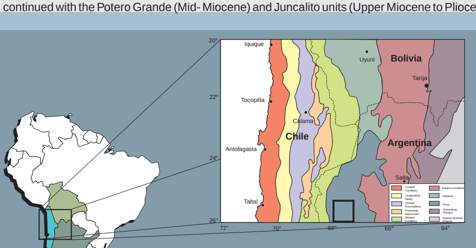


Figure 1

Location of the Salar de Antofalla area in the Central Andes.

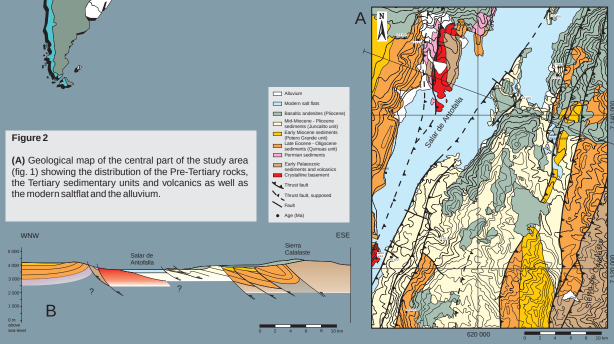


Figure 2

(A) Geological map of the central part of the study area (fig. 1) showing the distribution of the Pre-Tertiary rocks, the Tertiary sedimentary units and volcanics as well as the modern saltflat and the alluvium.

Structural control on sedimentary evolution

In the eastern part of the Salar de Antofalla the late Tertiary tectonic activity culminated during the mid-Miocene Quechua phase. Compressional events produced a series of westvergent folds and thrusts stretching along the entire length of the present Salar de Antofalla. Thrust-related frontal ramps produced topographic highs in the Sierra Calalaste area and led to the development of a narrow, highly elongated basin. Its western margin was tectonically passive and formed a flat upland, from which no significant amounts of detritus were delivered.

The facies distribution patterns of the mid-Miocene to Pliocene sediments (Juncalito unit) were controlled as follows (Fig. 3, 4): Thrust-tectonic induced sedimentation started with coarse alluvial fan sediments, deposited directly at the eastern basin margin. The alluvial fan conglomerates pass basinward into playa mud and sandflat deposits. Ceased tectonic activity between 10 and 4 Ma terminated the coarse-grained sedimentation. Lacustrine carbonates and sulfates developed next to the border of the fan bodies. This calcareous lacustrine environment is thought to be linked to a stage of relative tectonic quiescence. In the center of the partially flooded basin up to 50 m thick halites deposited simultaneously. Following, renewed shortening (Diaguita phase) with folding and thrusting of the entire succession resumed. This tectonic event triggered another basinward progradation of alluvial fan bodies. Continuation of the compressive tectonic activity initiated the final deformation, followed by the development of the modern alluvial fan complexes and the present salt flats.

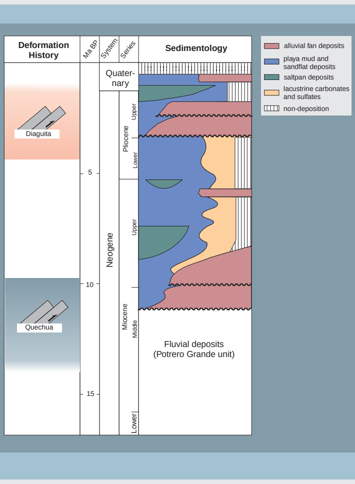


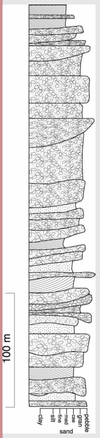
Figure 3

Tectonosedimentary chart of the Mid-Miocene to Pliocene Juncalito unit in the eastern part of the Salar de Antofalla basin.

The basin evolution in the Salar de Antofalla area in late Tertiary times is characterized by a compressional environment, an intramontane setting and a thrust tectonic-induced sedimentation. Due to its asymmetric shape, the facies distribution is wedge-shaped and unidirectional. Further features are the narrow and highly elongated shape.

According to basin models (e.g. JORDAN, 1995) the basin can be classified as a broken-foreland basin. Its development is based on the differentiation of the broad Eocene-Oligocene (retroarc) foreland basin. Due to basement-cored uplifts, numerous narrow basins with internal drainage appeared in the Southern Puna.

Alluvial fan deposits



The remnants of the late Tertiary alluvial fan sediments are found along the eastern margin of the accumulation area. The fan bodies formed directly adjacent to the topographic high induced by the contemporary thrust belt. They merge to form wedge-shape bajada deposits with a lateral extension of 2 to 5 km. The deposits are mainly composed of conglomerates and subordinated conglomeratic sandstones, reaching thicknesses up to several hundred metres. They contain boulders (ranging from 0.2 to 1 m in diameter), which originate from adjacent early Paleozoic and Paleogene strata. Several mechanisms of sediment transport were observed. The sheet-like shape and the minimal evidence of cut banks and bar formations suggest that the dominant mechanism of sediment transport was from debris or mud sheet flows which spread over large areas of the fan surface.

Figure 4-1

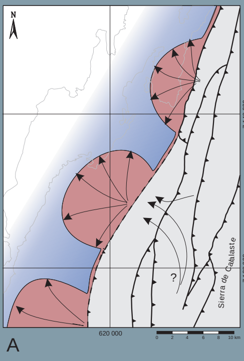
Coarse-grained alluvial fan deposits in the lower part of the Juncalito unit. The white horizons are volcanoclastic breccias (presumably lahar sediments) covering the alluvial fan sediments. Radiometric dating verifies a late Miocene age (9,1 Ma ± 0,3).

Figure 4

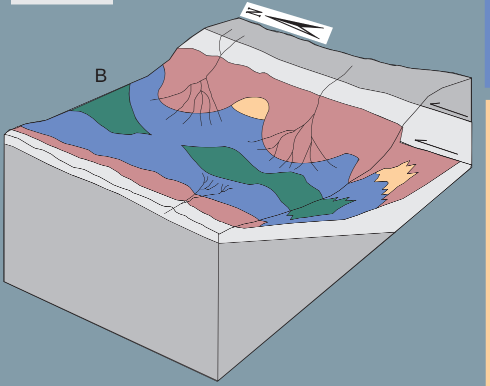
(A) Facies distribution in the basal part of the Miocene-Pliocene Juncalito unit deposited in the eastern part of the Salar de Antofalla basin. The western part is not exposed.

(B) Facies mosaic in the Salar de Antofalla basin during the late Miocene and the Pliocene. The facies distribution is significantly influenced by development of thrust-related ramps on the eastern margin. The source area included early Paleozoic low-grade metamorphic sediments and volcanics (dark gray) as well as sedimentary rocks of late Eocene to Oligocene age (light gray).

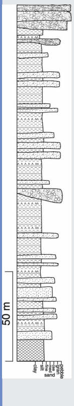
The facies associations (see also fig. 3) are described in detail in the surrounding boxes.



- 🟥 alluvial fan deposits
- 🟦 playa mud and sandflat deposits
- 🟩 saltpan deposits
- 🟧 lacustrine carbonates and sulfates



Playa mud and sandflat deposits



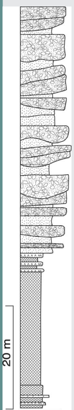
Most typical features are red mudstones/siltstones which are commonly massive and more rarely display mm-scale parallel laminae. Desiccation cracks and interbedded gypsum/anhydrite and halite layers are frequently observed. Subordinated are coarse-grained sheet sandstones showing horizontal to low-angle cross stratification and a sharp erosional base contact.

The sheet geometry, large lateral extent, and relatively uniform thickness suggests that the silt and sandstones represent distal sheetflows in a playa mud and sandflat environment. The intercalated evaporites indicate that parts were formed as ephemeral efflorescent crusts on saline mudflats.

Figure 4-2

Reddish sand and siltstones, representing distal sheetflows in a playa mud and sandflat environment. The intercalated, white-coloured layers consist of gypsum/anhydrite. They indicate a deposition as ephemeral efflorescent crusts on saline mudflats.

Saltpan deposits

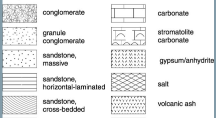


This facies is characterized by an abundance of saline minerals. The deposits are mainly cyclic and consist of alternating millimeter- to decimetre-scale layers of halite and mud. They represent saline lakes producing successive layers of salt by repeated flooding and subsequent reprecipitation.

In the central part of the basin the salt pan deposits can reach a thickness of 50 m. The maximum spatial distribution was achieved during periods of tectonic stability due to a decreasing clastic input.

Figure 4-3

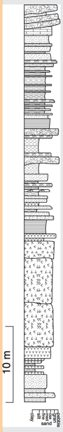
Approximately 30 m thick halite horizon, deposited in an ephemeral saline lake in distal parts of the basin. These saltpan deposits are disconformably overlain by conglomerates and sandstones of a prograding alluvial fan complex (see also log).



Legend

▨	conglomerate	▨	carbonate
▨	granule conglomerate	▨	stromatolite carbonate
▨	sandstone, massive	▨	gypsum/anhydrite
▨	sandstone, horizontal-laminated	▨	salt
▨	sandstone, cross-bedded	▨	volcanic ash
▨	pelite	▨	volcanoclastic breccie

Lacustrine carbonates and sulfates



This facies is dominated by gypsum/anhydrite horizons, grey marls and white limestones which contain predominantly stromatolites and oolites. Mud and siltstones and fine- to coarse-grained, gravelly sandstones as well as several up to 10 m thick volcanoclastic layers are interbedded. Horizons of symmetrical wave-ripples and bioturbation are common in both mudstones and siltstones.

The lacustrine facies interdigitates with the alluvial fans, the saltpan and the mudflat deposits. Its spatial distribution is predominantly influenced by the location of the deposited alluvial fan systems. Mainly the carbonates and sulfates hem around their front. In areas with low clastic input, they additionally occur in the wedge between alluvial fans directly at marginal parts.

Figure 4-4

Interbedded carbonates and sulfates of a marginal-lacustrine environment. At the top of the visible white-coloured succession up to 50 cm thick stromatolites appear. The lower part is dominated by volcanic ashes and volcanoclastic breccias. They yielded a biotite K-Ar age 4,6 Ma ± 0,5.

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