THE NORTH PATAGONIAN ALTIPLANO AND THE SOMÓN CURÁ BASALTIC PLATEAU

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ABSTRACT – For some time it has been considered that the Somón Curá basaltic plateau, at the edge of the North Patagonian Massif, was originated by inversion of relief. Recent observations allowed the hypothesis that the generation of the North Patagonian altiplano or plateau precedes the basaltic flows of the Somún Curá plateau. The Roca Formation marine sediments are used as a guide stratum to reconstruct the uplift history of the North Patagonian Massif. It is proposed that the 100,000 km^2 Cretaceous planation surface of the North Patagonian Massif was uplifted in early Oligocene times, and that the 15,000 km^2 of basalts that erupted on its surface immediately after (Oligocene-early Miocene) may be related to the same processes that led to the uplift.
Keywords: Altiplano, plateau, planation surface, uplift, basalts.

RESUMEN – *E. Aragón, E.Y. Aguilera, C.E. Cavarozzi, A. Ribot - El altiplano Nordpatagónico y la meseta basaltica Somón Curá*. Por algún tiempo se ha considerado que el plateau basáltico de Somón Curá situado en el borde del Macizo Norpatagónico fue originado por inversión de relieve. Observaciones recientes han permitido la hipótesis de que la generación de un altiplano o Plateau Norpatagónico precede la emisión de los flujos de lava del plateau basáltico de Somún Curá. Los sedimentos marinos de la Formación Roca son utilizados como estrato guía para reconstruir la historia de levantamiento del Macizo Norpatagónico. Se propone que la superficie de planación Cretácica de 100,000 km^2 del Macizo Norpatagónico fue levantada en el Olicogeno temprano, y que los 15,000 km^2 de basaltos que se extrudieron sobre su superficie inmediatamente después (Oligoceno-Mioceno temprano) podrían ser relacionadas al mismo proceso que llevo al levantamiento del Macizo.
Palabras clave: Altiplano, meseta, la superficie de aplanamiento, levantamiento, basaltos.

INTRODUCTION

Northern Patagonia Extra-Andean region gathers several provinces and tectonic-morphological geological units, arranged in a central North Patagonian Massif surrounded by the Neuquén Basin to the Northwest, the Colorado Basin to the Northeast, the Ñirihuau Basin to the West-Southwest, and the Cañadón Asfalto Basin to the South (Figure 1). The North Patagonian Massif is composed of Proterozoic and Eo-Palaeozoic metamorphic rocks intruded by Ordovician, Carboniferous and Permian igneous bodies, followed by Triassic and Jurassic volcanic complexes (Ramos, 1999) It is covered by a thin sedimentary sequence of upper Cretaceous and lower Tertiary non-deformed continental-marine sediments. The peripheral basins differ in ages from Jurassic to lower Tertiary times. Most of the central and south-eastern part of the Massif is covered by 15,000 km^2 of basalts of Oligocene-early Miocene age (Ardolino, 1981; Corbella, 1984; Franchi et al., 1984 and references therein).

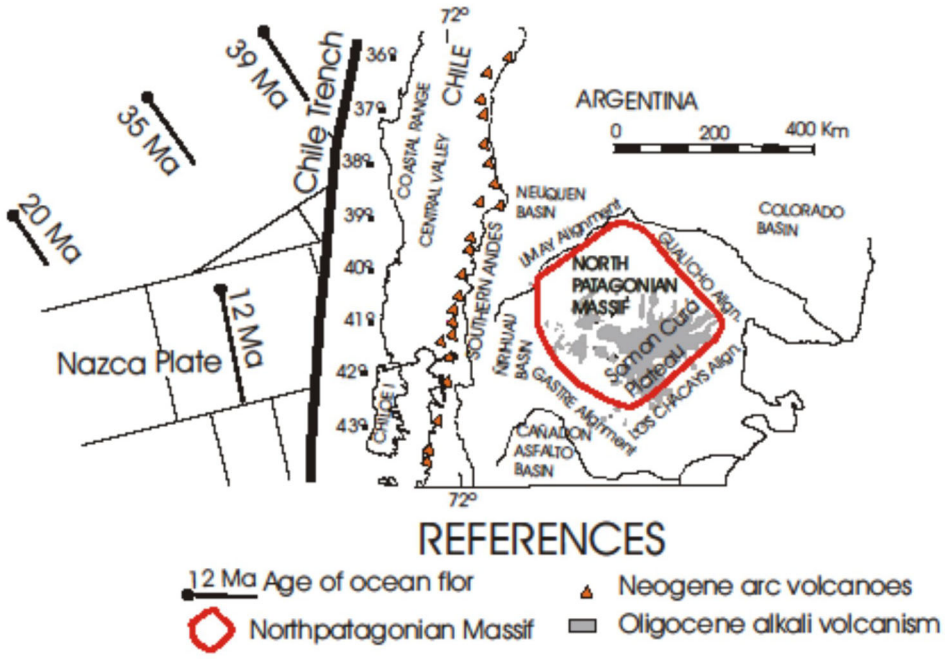

FIGURE 1. Main geological features of Northern Patagonia.

The North Patagonian Massif shows a comparatively flat surface at an average elevation of 1200 meters (Coira, 1979; Nullo, 1978; Franchi and Sepúlveda, 1983) that outstands 500 to 700 meters from the surrounding country and peripheral rivers (the Río Chubut to the south and the Río Negro to the north), suggesting that this high-lying tableland is an altiplano or a plateau. Previous paleogeographic and geomorphologic studies (Rabassa, 1978; González Díaz and Malagnino, 1984; Franchi et al., 1984; Corbella, 1984; Aguilera, 2006) show that the area had been subject to erosion from mid-Jurassic to upper Cretaceous times. A plateau is a comparatively flat area of great extent and elevation (more than 150-300 m in altitude) above the adjacent country. A large part of its total surface is at or near the summit level, and at least one of its sides is limited by an abrupt descending slope, which may be of tectonic, residual or volcanic origin.

The genesis of the Somón Curá plateau is a case of debate. For some authors the plateau is mainly related to the Somón Curá plateau basalts, and a consequence of inversion of the volcanic relief (Ardolino et al., 2008). This proposal considers that the main plateau or altiplano is consequence of the uplift of the North Patagonian Massif tableland (Aragón et al., 2008, 2009), taking the Somón Curá plateau basalts as a second plateau feature above the Massif tableland.

The purpose of this paper is to discuss the evolution of the Plateau developed at the North Patagonian Massif tableland, and to try to constrain the temporal span of the stages that took place to develop the present day plateau.

THE NORTH PATAGONIAN MASSIF

The Igneous-metamorphic core of the North Patagonian Massif is constrained by four major alignments: the Gastre alignment to the southwest, the Chacays alignment to the southeast, the Gualicho alignment to the northeast and the Limay alignment to the northwest. It covers a surface of 100,000 km^2 (Figure 1), built with Eo-Palaeozoic metamorphic rocks, Ordovician, Carboniferous, Permian and Jurassic plutonic rocks, and the Triassic and Jurassic volcanic complexes. Sedimentary cover is sparse, mostly restricted to thin deposits of upper Cretaceous continental and Maastrichtian-Danian marine sediments belonging to the Roca Formation, covered by Oligocene-Miocene basalt flows (Ardolino, 1981) and a few continental Eocene-Oligocene sediments.

The north-eastern and south-eastern boundaries are also featured by the development of the Valcheta and the Tierra Colorada closed depressions respectively (Figures 2, 3 and 4).

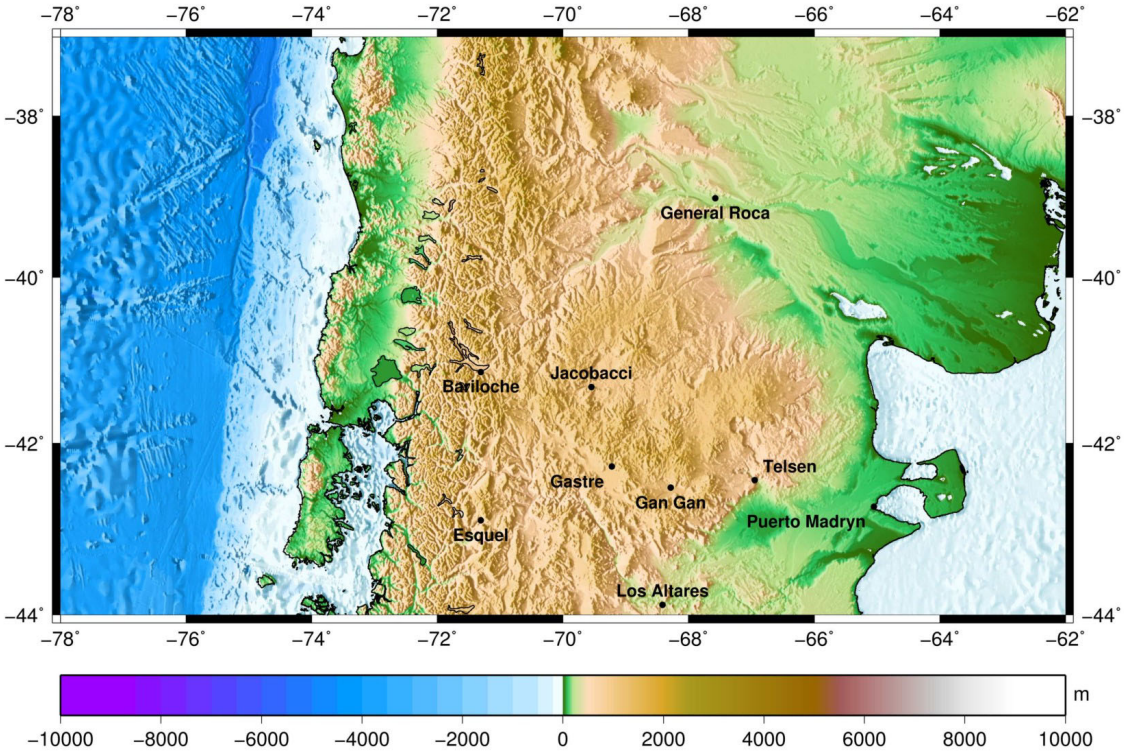

FIGURE 2. Topography of Northern Patagonia.

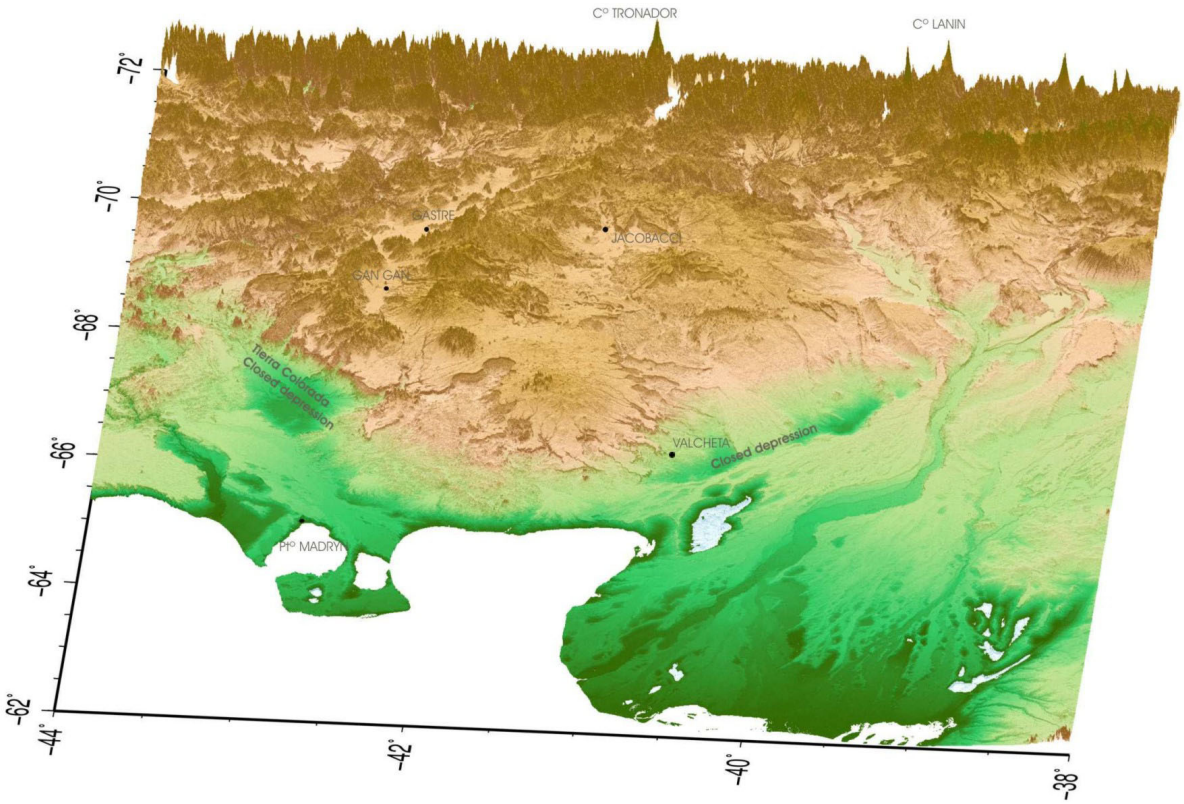

FIGURE 3. 3D topographic view of Northern Patagonia from the east.

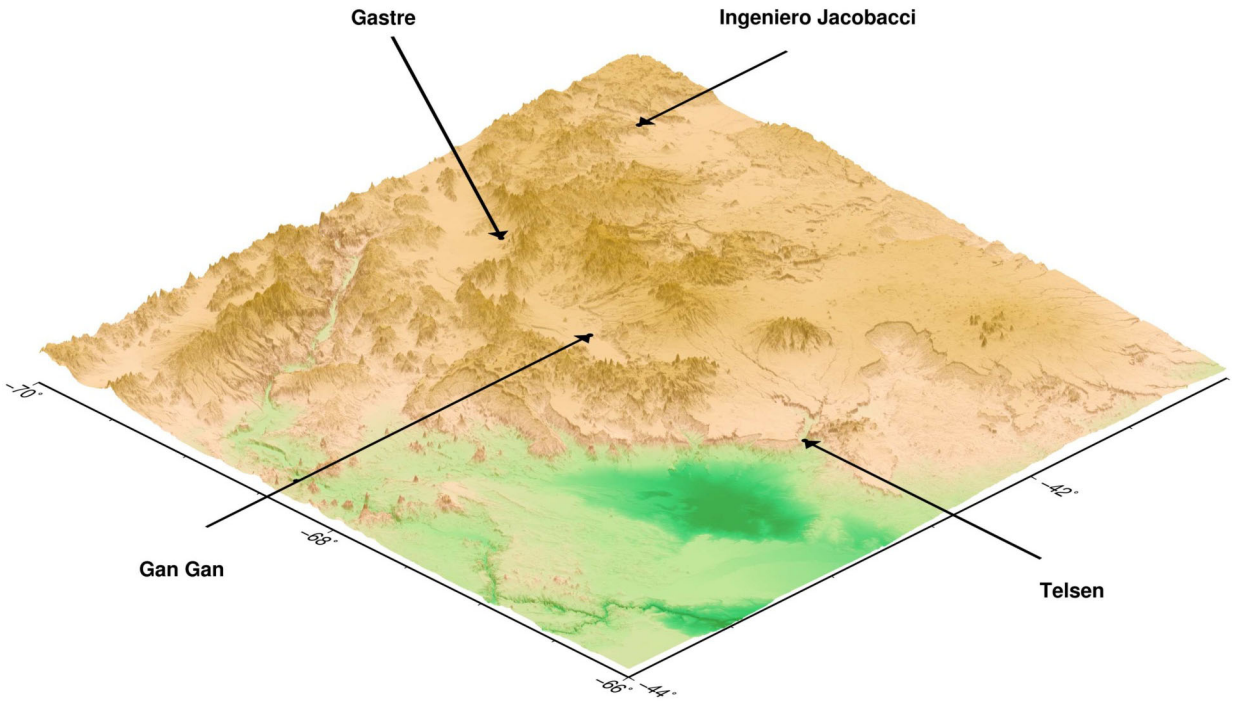

FIGURE 4. 3D topographic view of Northpatagonian Massif from the south-east.

MAIN MORPHOLOGY-EVOLUTION STAGES

Planation Surface Stage

The North Patagonian Massif shows a smooth topographic surface developed on the basement rocks (Figures 5 and 6), resembling a tableland. The time to develop the tableland is constrained by the latest mid-Jurassic volcanic rocks and the upper Cretaceous thin sedimentation cover that drapes great extents of the tableland (González Díaz and Malagnino, 1984; Aguilera, 2006; Aragón et al., 2003). The nature of this tableland was referred to as a peneplain (González Díaz and Malagnino, 1984; Aragón et al., 2003), but recent works suggest that it should be referred to as a planation surface instead (Aguilera, 2006; Aragón et al., 2005), and correlate it to the Gondwana planation surface of King (1967).

FIGURE 5. Gondwana Planation surface on Permian granitoids at the Northpatagonian Massif.

FIGURE 6. Gondwana Planation surface at the Northpatagonian Massif, and the Colitoro Plateau basalts on the background.

Flood Stage

Most of the massif tableland is covered by a thin drape of upper Cretaceous continental sediments (Figures 7 and 8) and shallow marine sediments (Roca Formation) of Danian-Maastrichtian age (Malumian, 1999, and references therein). These marine sediments extend also to the surrounding basins and country rocks. The deposits of this broad transgression will be used as a guide stratum to understand the uplift history of the massif with respect to the surrounding country rocks.

Uplift and Basalt Flows Stage

All of the marine sediments of the Roca Formation at the North Patagonian Massif are non-deformed, retain a sub-horizontal position and are covered by Oligocene basalts (Figure 7). The prevailing lack of sediments between these two units is one of the outstanding features. The contact between the Danian marine sediments and the Oligocene basalts at the Massif stands at an average altitude of 1200 meters (Meseta Carri Laufquen, Meseta Colitoro, El Cain at Somón Curá plateau). But, contrarily, at the Massif surrounding country rocks along the Río Chubut to the south and the Río Negro to the north, the Danian marine sediments stand at altitudes that range about 300-500 meters.

One of the outstanding features of the Oligocene-early Miocene basalts is that at the Massif tableland, they have a table like distribution. There, erosion has caused relief reversal of few tens of meters, but as the lava flows reach the rim of the North Patagonian Massif, they spill down to the surrounding country rocks as cascades, showing an abrupt descent. Several of these features can be seen in Figures 4 and 5. The south-eastern side of the Massif has the most abrupt descent. There, the lava flowed moved downwards 500 meters from the edge of the plateau to the locality of Gan Gan, in only 20 kilometers.

FIGURE 7. Gondwana Planation surface at the Northpatagonian Massif, draped by upper Cretaceous-Danian sediments and Oligocene basalt flows, showing relief inversion.

FIGURE 8. Gondwana Planation surface at the Northpatagonian Massif, with a smooth valley filled with upper Cretaceous sediments and Miocene basalt flows, showing relief inversion.

DISCUSSION AND CONCLUDING REMARKS

The differences of field relationships of the Roca Formation among various outcrops in the North Patagonian Massif (its total surface being at or near the summit level of 1200 meters) from those at the surrounding country rocks (along the Río Chubut and Río Negro at 300-500 meters) and the abrupt descent of the country rocks with respect to the Massif, suggest the following constrains in the uplift history of the region:

a) The sparse and little sedimentation between the Danian marine sediments and the Oligocene basalts at the Massif, along such a broad area and the average altitude of the contact levelled at 1200 meters, suggests that the uplift of the Massif took place as a regional uplift and not as independent blocks;

b) The abrupt descent from the Massif to the country rocks suggests that the uplift of the Massif to 1200 meters is independent from the rising of the surrounding country rocks that only reached 500 meters;

c) It is clear that the Danian marine sedimentation and the little Eocene-Oligocene subsequent

sedimentation constrain the beginning of uplift (at least) down to the Eocene or Early Oligocene.

d) The Oligocene-lower Miocene basalts that abruptly descend (from the Massif) more than 500 meters to the surrounding country rocks, show that the Massif tableland had attain the altitude and morphology of a plateau or an altiplano at least in early Oligocene times.

From the aforementioned arguments it is suggested that the North Patagonian Massif tableland was subject to uplift in the early Oligocene independently from its surrounding country rocks until it formed a plateau or altiplano, and that the Oligocene-Miocene basalts that erupted and flowed on top of it immediately after the uplift, may have had an origin closely related to processes that caused the uplift.

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BIBLIOGRAPHIC REFERENCES

1. AGUILERA, E.Y. **Identificación y distribución de distintas superficies geomorfológicas de escaso relieve local, por medio de sensores remotos en el área del Macizo Nordpatagónico, Provincia de Río Negro**. Argentina, 2006, 230 p. Doctoral Thesis – Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata. Unpublished.
2. ARAGÓN, E.; GONZÁLEZ, P.; AGUILERA, E.Y.; CAVAROZZI, C.; LLAMBÍAS, E.; RIVALENTI, G. Thermal divide andesites-trachytes, petrologic evidence, and implications from Jurassic north Patagonian massif alkaline volcanism. **Journal of South America Earth Science**, v. 16, n. 3, p. 91-103, 2003.
3. ARAGÓN, E.; CARROLL, A.R.; AGUILERA, E.Y.; CAVAROZZI, C. Ancient Gondwana Landforms in Patagonia. In: GONDWANA 12, "GEOLOGICAL AND BIOLOGICAL HERITAGE OF GONDWANA", Mendoza, Argentina. **Abstracts...** Mendoza: Academia Nacional de Ciencias, p. 46, 2005.
4. ARAGÓN, E.; AGUILERA, E.Y.; CAVAROZZI, C.; UBALDÓN, M.C.; RIBOT, A. La Caldera de Piedra Parada. Un volcán gigante de 50 millones de años, testimonio de cambios. In: Sitios de Interés Geológico, Ed. Servicio Geológico Minero Argentino. **Anales**, v. 46, n. 2, p. 669-682, 2008.
5. ARAGÓN, E.; GOIN, F.J.; AGUILERA, E.Y.; WOODBURNE, M.O.; CARLINI, A.A.; ROGGIERO, M.F. Paleogeography and paleoenvironments of Central Patagonia from the Late Cretaceous to the Miocene: The Paleogene Andean gap and the rise of de North Patagonian Altiplano. In: WORKSHOP "PALEO-GEOGRAPHY AND PALEOCLIMATOLOGY OF PATAGONIA: EFFECTS ON BIODIVERSITY"- UNLP-Dalhousie University- CONICET- ANPCyT- National Science Foundation: PIRE (Partnerships for International Research & Education), La Plata. **Abstracts...** 2009.
6. ARDOLINO, A. El volcanismo Cenozoico del borde suroccidental de la Meseta de Somún Curá. Provincia del Chubut. In: CONGRESO GEOLÓGICO ARGENTINO, 8, 1981. **Actas...** v. 3, p. 7-23, 1981.
7. ARDOLINO, A.; FRANCHI, M.; REMESAL, M.; SALANI, F. La Meseta de Somún Curá. In: Sitios de Interés Geológico, Ed. Servicio Geológico Minero Argentino. **Anales**, v. 46, n. 2, p. 643-658, 2008.
8. CORBELLA, H. El vulcanismo de la Altiplanicie de Somuncura. In: CONGRESO GEOLOGICO ARGENTINO, 9, 1984. **Relatorio** I, v. 10, p. 267-300, 1984.
9. FRANCHI, M.B.; NULLO, F.E.; SEPÚLVEDA, E.G.; ULIANA, M.A. Las sedimentitas Terciarias. In: CONGRESO GEOLÓGICO ARGENTINO, 9, 1984. **Relatorio** I, v. 9, p. 215-266, 1984.
10. GONZÁLEZ DÍAZ, E.F. & MALAGNINO, E.C. Geomorfología de la Provincia de Río Negro. In: CONGRESO GEOLÓGICO ARGENTINO, 9, 1984. **Relatorio** II, p. 1-159, 1984.
11. KING, L.C. **The morphology of the earth**. Edinburg, Eds. Oliver & Boyd, 726 p. , 1967.
12. MALUMIAN, N. **La sedimentación y el volcanismo Terciarios en la Patagonia extraandina, Geología Argentina**. In: CAMINOS, R. (Ed.), Servicio Geológico Nacional, Anales v. 29, n. 18, p. 557-578, 1999.
13. RABASSA, J. Paleorrelieves Cenozoicos en la región de Pilcaniyeu-Comallo, Provincia de Río Negro. In: CONGRESO GEOLÓGICO ARGENTINO, 7, 1978, Neuquén. **Actas...** Neuquén, n. 2, p. 77-87, 1978.
14. RAMOS, V.A. **Provincias Geológicas Argentinas, Geología Argentina**. In: CAMINOS, R. (Ed.), Servicio Geológico Nacional, Anales v. 29, n. 3, p. 41-96, 1999.

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