



## PERALUMINOUS GRANITES IN THE NORTHEASTERN SECTOR OF THE NORTH PATAGONIAN MASSIF.

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## INTRODUCTION

In Chile Late Palaeozoic to Early Mesozoic granitoids occur in the Andean Cordillera and the Coast Range (1) as far south as south of 38°S. Beyond this, these "Gondwana" granitic rocks are only found farther inland specially in the North Patagonian Massif of Argentina. (NPM, see Fig.1).

In the northern area of the NPM, intrusive igneous rocks have been reported by several authors. (2, 3, 4 and 5). In the main areas of the Somoncurá Batholith, La Esperanza and Nahuel Niyeu, the igneous rocks have been interpreted (5) as representing a single cycle of igneous activity with an older plutonic and a younger plutonic-volcanic association.

Both associations were considered to be Permo-Carboniferous in age. Recent dating has emphasised the difficulty of distinguishing Palaeozoic from Jurassic units. (5)

In this paper we present new observations on field relations as well as petrological, geochemical and geochronological data for granitoids in the northeastern sector of the NPM around Sierra de Pailemán.

The characteristics of the intrusive rocks and their metamorphic envelope are compared with better known Permo-Triassic plutonic and volcanic sequences in the north-central sector of the NPM and Frontal Cordillera of northwestern Argentina.

## GEOLOGICAL RELATIONS AND COUNTRY ROCKS

The Arroyo Tembrao-Arroyo Pailemán area is located in the northeastern sector of NPM, northward to the Sierra de Pailemán. (Fig. 1). The studied area covers near 160 km<sup>2</sup>, between 40° 45' - 41° 10'S and 65° 40' - 66°W.

Granodiorites, granites, and pegmatitic and aplitic veins intrude a metamorphic basement composed of schists, phyllites, amphibolites and calcareous rocks of the Mina Gonzalito Complex (6). A minimum age (Rb/Sr whole-rock isochron 850±50 Ma) for the later was determined, (7).

## COUNTRY ROCKS

The metamorphic basement is widely represented in the area between Arroyo Tembrao and Arroyo Pailemán. The metamorphic rocks are very well exposed 7 km north to the Pto. Contreras, near to the Arroyo Pailemán. They are quartz-feldspar and biotite-muscovite schists and hornblende and diopside amphibolites. General strike cleavage is N10°-40°W, and dip 10°-38°NE. Other cleavage directions are N30°-50°E and dip 40°-60°SE. The more abundant schists are those composed by biotite-muscovite, quartz and plagioclase. Garnet, zircon and fluorite are accessory minerals. Fine grained, red quartz-feldspar schists, are less abundant. They exhibit a granoblastic to lepidoblastic texture and are composed by microcline, quartz, oligoclase, biotite and muscovite. Their cleavage is not very well developed.

Pegmatitic veins are developed in this area. They are up to 5 cm wide, 1-2 m long, crossing the metamorphites in all directions. Amphibolites are restricted to very small bodies (up to 30 m long,

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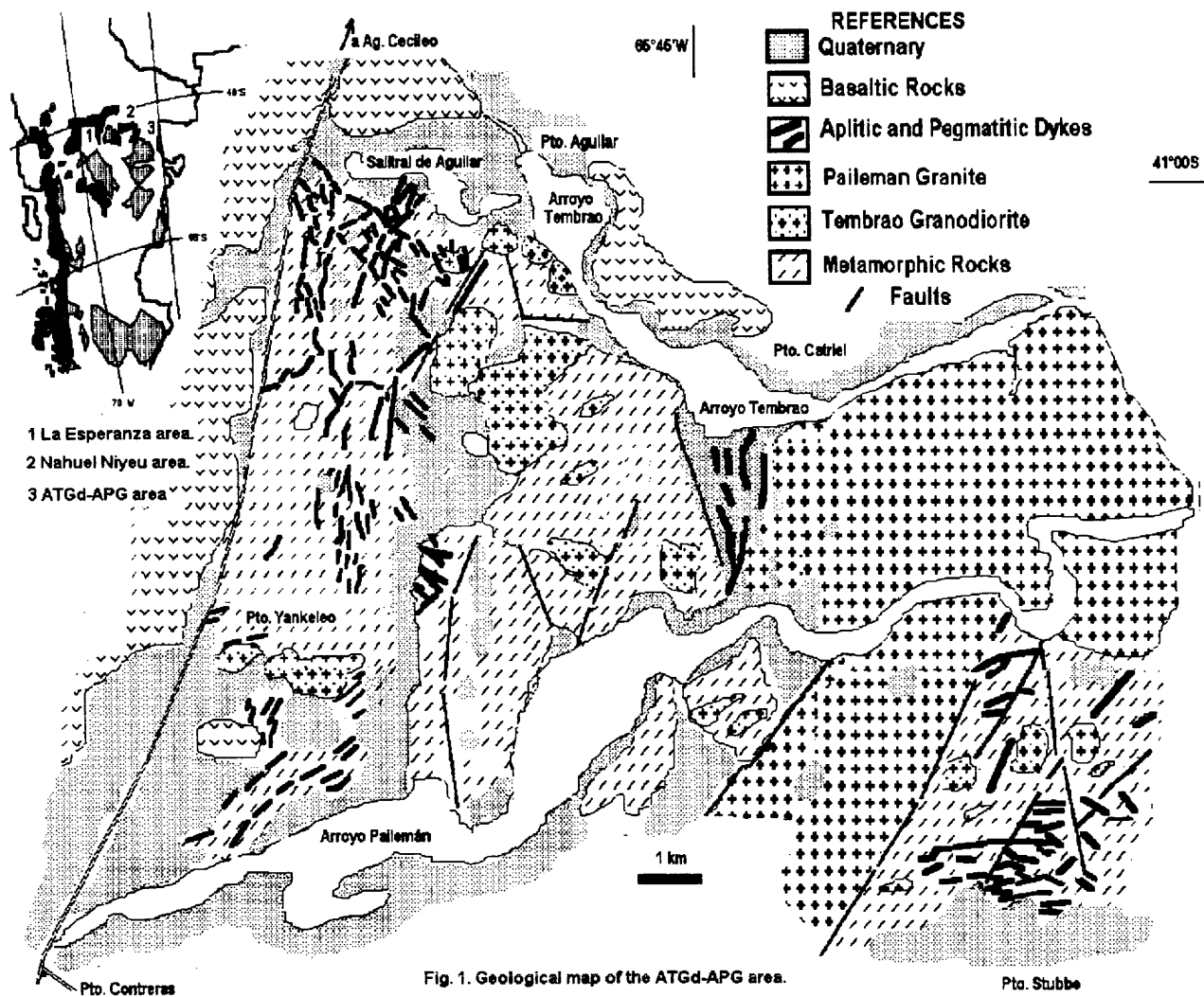


Fig. 1. Geological map of the ATGd-APG area.

15 m wide) with strike N40°W and dip 30°NE. There are two varieties, hornblende amphibolite and diopside amphibolite. Magnetite and titanite are the common accessory minerals.

South to Pto. Aguilar, near to Arroyo Tembrao the metamorphic rock comprises calcareous mudstones with garnet, tuffaceous sandstones and pelites in a regularly interbedded sequence. Schists and micacites were also recognized. This sequence has a N30°W strike and dip 25° to the NE.

Near to the route to Aguada Cecilio, schists and micacites appear in scattered outcrops and as roof pendant on the granodiorite. The rocks show stratification and incipient development of migmatitic veins with a N10°W strike. In this area the metamorphic rocks exhibit strong changes in their strikes (N60°W dip 65 SW-80 NE), owing to the intrusion of the Arroyo Tembrao Granodiorite

North to the Pto. Stubbe the metamorphic rocks are poorly represented. They are micaceous schists and amphibolites with a N40°E strike and nearly vertical dip.

Veins and dikes of a pegmatitic pink granite, with tourmaline, 10 cm to 3 m wide, 6 m long are cross-cutting the former.

#### ARROYO TEMBRAO GRANODIORITE (ATGd)

A coarse grained, gray biotitic granodiorite, intruding the metamorphic rocks is well exposed south to the Pto. Aguilar, extending to the west (Fig. 1). It outcrops as ellipsoidal bodies with strikes N30°E and dips 40°NW.

It is intruded by the Arroyo Pailemán Granite and by aplite and pegmatite dikes. Abundant inclusions of biotite up to 25 cm in diameter were found in the granodiorite.

The ATGd has a homogeneous, equigranular hipidiomorfic texture. The plagioclase is well zoned calcic oligoclase, in euhedral crystals up to 2mm long. Myrmekitic textures and replacement for quartz and K-feldspar are common. Anhedral quartz crystals present plagioclase inclusions and shadowy extinction.

The K-feldspar consist of anhedral to subhedral crystals of perthitic microcline and orthoclase. Medium

grained biotite is abundant and shows inclusions of fluorite and zircon. Figure 2 shows the modal composition of ATGd.

SiO<sub>2</sub> varies from 69.05% to 69.31%. The intrusives display transitions from metaluminous to peraluminous compositions. Likewise, the dominant peraluminous character is more than 1, and normative corundum is also more than 1% (see Fig.3).

#### ARROYO PAILEMÁN GRANITE (APG)

The APG is a pink to grey-pink body with an equigranular hipidiomorfic, medium grained texture, conforming an elongated body of 10 km long in NE direction and of 4 km wide in NE direction intruding the ATGd and the country rocks.

The APG is intruded by aplite and pegmatite veins (N70°W). It is composed by K-feldspar (orthoclase-microcline), quartz and plagioclase (An<sub>12</sub>An<sub>16</sub>). Muscovite is the more abundant micaceous mineral, but biotite is present. Garnet, zircon, fluorite and titanite are accessory minerals. Myrmekitic textures are common. Mafic inclusions as in the ATGd were not found.

Figure 2 shows the modal composition of the APG.

SiO<sub>2</sub> varies from 72.25% to 74.85%. The APG peraluminosity is also shown in Fig.3. In Harker diagrams, the ATGd, the APG and the aplite-pegmatitic granites plot in two separate fields, distinguishing the less differentiated granodiorites from medium-grained monzogranites and the more differentiated aplites.

#### APLITE AND PEGMATITE DIKES

Aplite and pegmatite granitic dikes with tourmaline are quite common in all the area. They are intruding the metamorphic rocks, the APG and the ATGd.

They are well represented in the western and in the eastern sectors. They show variable strikes between N60°W and N30°E and are up to 200 m long and 4 m wide. As is shown in the map the dikes have ramifying branches of coarse grained pink granite with strong foliation in NW direction, dipping 30-55°NE.

The pegmatite dikes are composed by biotite and tourmaline, whereas the aplite dikes are composed by

muscovite and tourmaline. They are of high silica type.

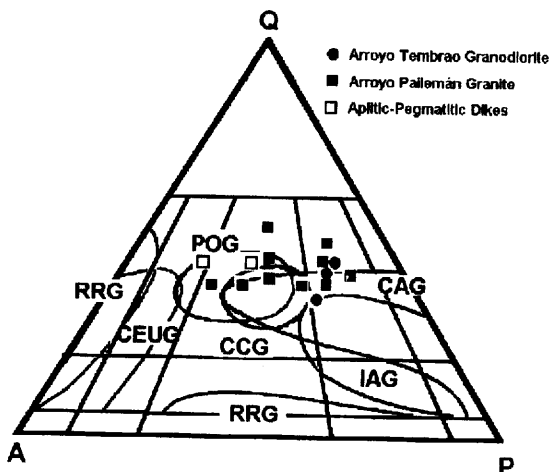


Fig. 2 Modal QAP diagram for the intrusive rocks of Pailemán

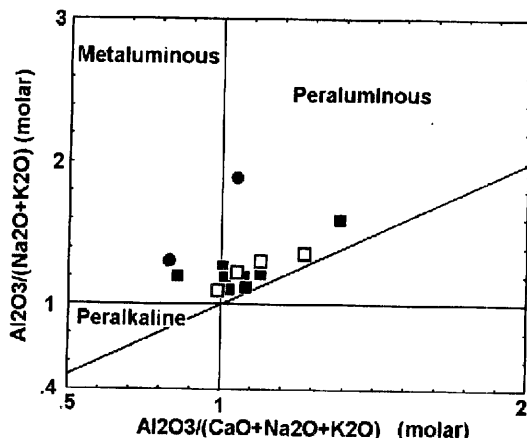


Fig. 3 Shand diagram for the intrusive rocks of Pailemán

#### GEOCHRONOLOGY

A suite of 14 whole rock samples was analysed at NIGL, Nottingham for Rb-Sr geochronology using the same techniques as in our recent work on the granitoids of the Somoncurá Batholith, (5). Data for the five samples of the APG plot on an isochron (Fig. 5) with a low value of MSWD (= 1.7) indicating that they meet statistical requirements for goodness-of-fit. This isochron, that is taken as dating crystallization of the APG, corresponds to an age of  $268 \pm 3$  Ma (Late early Permian), in good agreement with a previous K/Ar whole rock age of  $270 \pm 10$  Ma for the same unit, (8). The initial  $^{87}\text{Sr}/^{86}\text{Sr}$  is  $0.7098 \pm 0.0001$ , signifying a relatively high crustal component in the magma.

The data points for the ATGd and other granitoids (all dikes) do not fit this isochron but form a cluster slightly below the lower end of the line (they mostly contain around 500-700 ppm Sr) with the exception of single garnet-tourmaline granite that plots above the top end of the isochron. Since field relations show that the ATGd was intruded by the APG this is consistent with a slightly older age for the

former, and a rather variable initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of about 0.708, perhaps due to variable amount of contamination of a liquid with an even lower primary  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio.

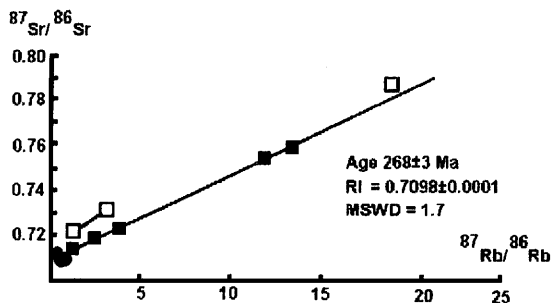


Fig. 5 Rb-Sr plot for whole rocks for the Sierra de Pailemán granitoids. The isochron shown is for samples of the Arroyo Pailemán Granite (closed squares). Data points for granite dikes are shown as open squares, the Arroyo Tembrao Granodiorites as closed circles.

COMPARISONS OF PAILEMAN GRANITOIDS WITH  
OTHER GONDWANA GRANITES

The age obtained in the APG (268±3 Ma) is slightly older but within the analytical error of the older granitoid units at La Esperanza in the north-central sector of the NPM (258±15 Ma and 259±16 Ma, 5). As the ATGd does not show geochemical or isotopic evidence for consanguinity, its age is still unclear, except that it was intruded by the APG. Nevertheless, both plutons were intruded at shallow levels, and we consider that they were emplaced during the same general episode of igneous activity.

In terms of their major elements chemistry, the ATGd and APG are broadly similar to their nearest neighbours in the NPM, the equigranular facies "medium grained" of the Navarrete Granodiorite and the biotite granite of the Flores Granite, respectively, both in the Nahuel Niyeu area, 50 km to the NW. The age of these is not well constrained, Rb-Sr whole rock data indicating an important Jurassic event (9), but their initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in Permian times would have been relatively low (< 0.706). The two mica APG shows a well defined peraluminous signature, which is a not a common feature in the plutonic-volcanic complexes of the NPM. Although the Middle Triassic leucogranites and ignimbrites of the Dos Lomas Complex are chemically peraluminous they never develop two-mica facies, with primary muscovite (10). The QAP compositional field of the Pailemán granitoids is quite distinct from typical trends of calcalkaline arc granitoids, resembling instead those of granites with important crustal contributions (see Fig. 2). Initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the APG (0,7097) is also much higher than normal mantle values and the range of values reported for the Permian and Triassic granites of the NPM (0,7054-0,7076; 11,5).

Permian granites also occur in Colangüil Batholith of the Frontal Cordillera of Argentina with ages mostly in the range 270-250 Ma (12) and initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of 0.705-0.709 (13). A single pluton is composed of

peraluminous S-type granite with high initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios (0,7110-0.713). However, the lithological evolution of the Colangüil suite in the modal QAP diagram is similar to those of continental arc granitoids (see Fig.1 of 12), a feature not shared by the Pailemán suite (Fig.2). Further regional and detailed studies are needed to better understand the connections between the Permian magmatism of the eastern and northern side of the NPM, and in turn the relations of the magmatism of the Frontal Cordillera and the NPM.

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