TIME CONSTRAINTS FOR THE TECTONIC EVOLUTION OF THE SW CORNER OF THE NORTH PATAGONIAN MASSIF, ARGENTINA.

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Keywords: K-Ar cooling ages-Late Palaeozoic- basement complexes-SW North Patagonian Massif

INTRODUCTION

The pre Jurassic basement of the western border of the North Patagonian Massif (NPM) is composed of metamorphic and igneous complexes that range from Devonian to Triassic (Rapela et al., 1992, Linares et al., 1997, López de Luchi et al., 1999, Varela et al., 1999, 2005, Ostera et al., 2001, Lucassen et al., 2004, among others). In the central and western areas of the NPM, the metamorphic basement is the Cushamen Formation (CF) whereas the older granitoids were encompassed as the Mamil Choique Granitoids (MCG, Dalla Salda et al., 1994, Cerredo and López de Luchi, 1998, López de Luchi and Cerredo, submitted). This basement is intruded by undeformed Permo-Triassic granitic units (López de Luchi et al., 2000). In spite of the available geochronological and isotopic data uncertainties about the timing of the metamorphism, magmatism, deformation and cooling of the igneous and metamorphic complexes still exist.

The aim of this paper is to present new K-Ar mineral ages for the Río Chico area (41º 40'-41º 55'S/70º-70 33'W) in order to discuss the timing of deformation and magmatism and the cooling of the metamorphic and igneous domains of the area. A comparison of these data with published relevant data of adjacent domains of the SW sector of the NPM is addressed.

GEOLOGICAL SETTING FOR THE RÍO CHICO-SIERRA DE MAMIL CHOIQUE AREA

Within the Rìo Chico-Sierra de Mamil Choique area the metamorphic series of Cushamen Formation are mainly composed of metasedimentary rocks (metragreywackes, metaquartzites) with minor metavolcanic interlayers. Medium-P regional metamorphism encompasses greenschist to upper amphibolite facies (López de Luchi and Cerredo, 1996, Cerredo 1997). The CF hosts amphibole-biotite tonalites, the Tunnel Tonalites (TT) and the Mamil Choique Granitoids (MCG, Dalla Salda et al., 1994, Cerredo and López de Luchi, 1998, López de Luchi and Cerredo, submitted). MCG consist of three peraluminous units: the banded Huenchuquil tonalites and granodiorites (HTG) and the Cerro Mojón biotite-muscovite monzogranites (CMG) which are intruded by the undeformed Nahuelfil monzogranites (NG, López de Luchi and Cerredo, submitted).

Two deformational phases (D_1 and D_2) accompanied by foliation development (S_1 and S_2) were distinguished in the CF. Peak metamorphism was synchronous with the penetrative main S_2 foliation. Two late deformations (D3 and D_4) affected both the metamorphic basement and the intrusive units. D3 originated folding, recrystallization and locally mylonitization in the CF, TT, and MCG. In the CF mylonitic textures are developed in relation to D_3 folding and a shearing event associated with andalusite-biotite-quartz assemblages along microshear zones. The metaluminous calc-alkaline TT emplaced within the D_2-D_3 time span based on both the absence of regional metamorphic assemblages and the widespread development of mylonitic textures associated with greenschist facies assemblages (Cerredo and López de Luchi, 1997, 1998). The HTG and the CMG show a continuum of submagmatic (relocation textures) to subsolid high-T deformation textures related to D_3 deformation (Cerredo and López de Luchi 1998). Therefore the HTG and the CMG emplacement was considered as synkinematic with D_3 whereas a post-D_3 emplacement was interpreted for the undeformed NG (López de Luchi and Cerredo, submitted). A U-Pb conventional zircon age of 272 ±2.2 Ma for HTG lead Varela et al. (2005) to relate the MCG with the Gondwanide cycle.

The youngest D_4 deformation produced brittle open folds of fairly constant NE axis, plunging both NE and SW (Cerredo 1997, Cerredo and López de Luchi, 1998, López de Luchi and Cerredo, 1996).

PREVIOUS GEOCHRONOLOGICAL DATA

Published geochronological data for the described units are presented in Table 1.

NEW GEOCHRONOLOGICAL DATA

Selected samples were subjected to K/Ar mica dating in the Geoscience Centre of the University in Göttingen. Details of argon and potassium analyses for the

laboratory in Göttingen are given in Wemmer (1991). Three new mica ages are presented (Table 2). A preliminary separation of two groups of older muscovite ages and younger biotite ages is delineated. A muscovite age was obtained for one sample of the Cushamen Formation which belongs to a fine-grained granitoid near to the discontinuous belt of D3 shear zones. The dated muscovite corresponds to locally oriented muscovite .

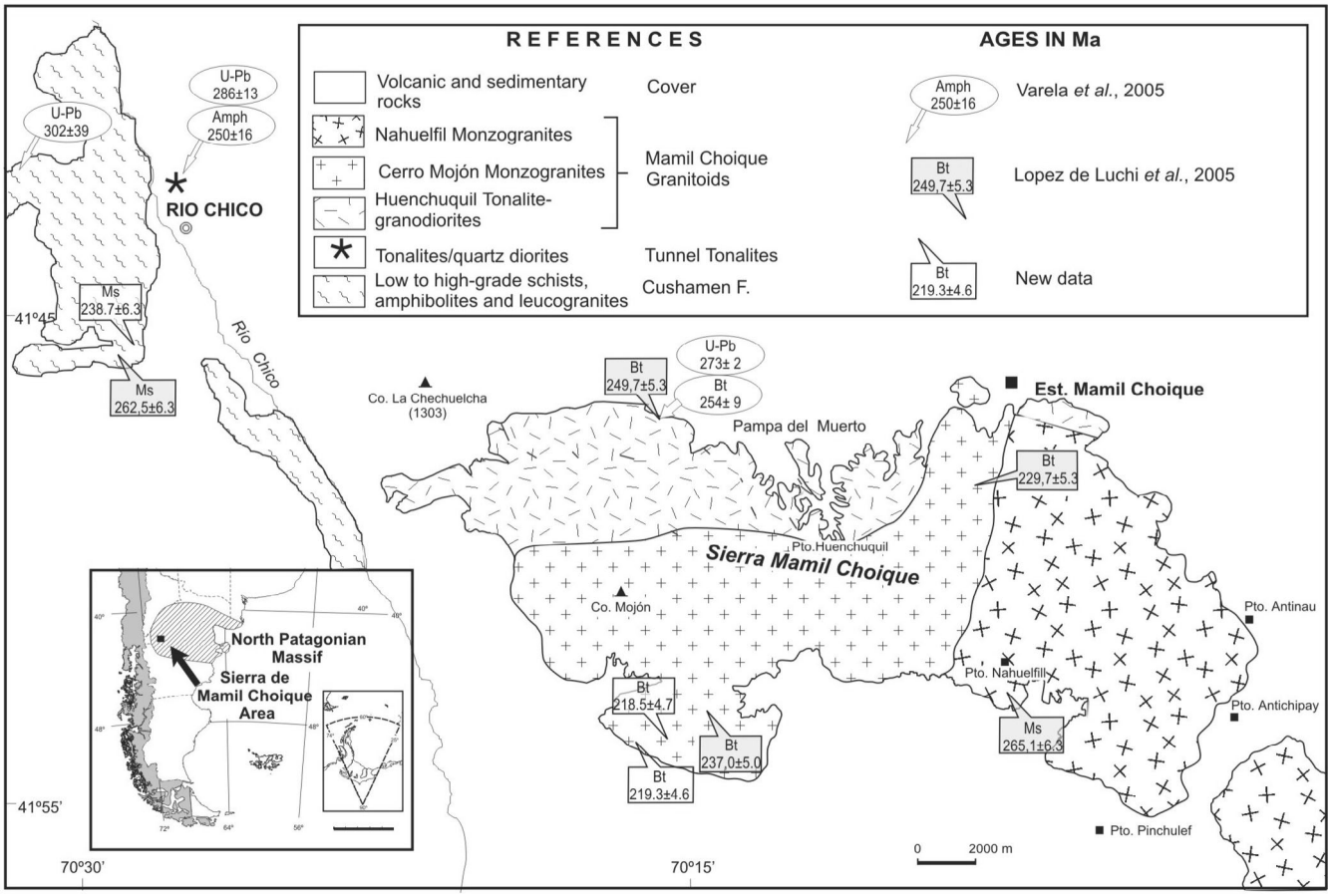

Figure 1: Geological sketch of the Río Chico-Sierra de Mamil Choique area.

crystals. Biotite ages were obtained from two samples which correspond to two different outcrops of undeformed porphyroid granitoids that are intruding the CMG as dykes or small stocks

DISCUSSION

The metamorphic basement of the SW border of NPM both at the studied area (Ostera et al., 2001) and elsewhere (Lucassen et al., 2004) has yielded ages which cluster within the Devonian. However, recently published Visean SHRIMP U-Pb zircon ages from the CF at the Chubut province were interpreted as detrital ages thus proposing a Carboniferous maximum age for the protoliths of the CF (Hervé et al., 2005). U-Pb conventional zircon ages of 302±39 Ma for a deformed leucogranite intruded in CF schists (Varela et al., 2005) may bracket the peak metamorphic conditions between 335 and ca. 300 Ma since the U-Pb conventional zircon age for the TT that was intruded after D2 is 286±13 Ma (Table 1). D3 developed a pervasive high temperature solid-state deformation with recrystallisation of plagioclase which requires a minimum temperature of at least 450ºC, i.e above the muscovite closure temperature (Blackenburg et al, 1989). The closure of the K/Ar isotopic system for muscovite blasts at 262.5± 6.3 Ma (Table 1) will approximate the time of cooling below the 420-350ºC isotherm of the basement domain. Therefore based on microstructural and geochronological data, D3 high temperature solid-state deformation in the CF is slightly older than 262, 5 Ma and postdates 286±13 Ma.

Our new muscovite K/Ar age of ca. 239 Ma from a CF schist may be interpreted as a cooling age implying then a new magmatic event or as documenting deformation-induced partial resetting. In this connection it is worthy to recall that Hames and Cheney (1997) were able to show that deformation is much more effective in resetting K–Ar based ages than static heating, i.e., temperature alone. Therefore, we suggest that the muscovite age quoted above is partially reset due to minor increments of deformation likely related to D4. This deformation-induced resetting is attributed to crystal lattice defects developed during local kinking and bending of pegmatitic muscovite, which significantly enhance Ar diffusivities, leading to partial loss of 40Ar* (Hames and Cheney, 1997).

The crystallization U/Pb zircon age of 273±2 Ma (Varela et al., 2005) for the HTG facies of the CMG is comparable within errors with the one reported for the Yancamil Granite (261±17 Ma, von Gosen and Loske, 2004) in the neighbouring Sierra de Calcatapul and the 267±27 Ma WR Rb/Sr isochron age for Sierra del Medio Granitoids (Rapela et al., 1992). The conventional U/Pb zircon age of 286±13 Ma (Varela et al., 2005) also fit within this time span. Therefore, along the SW border of the NPM Early-Middle Permian times would have been characterized by widespread magmatic events.

Table 1: Summary of selected published ages for the area of Río Chico-Sierra de Mamil Choique. Sources: 1: Ostera *et al*., 2001; 2: Duhart *et al*., 2002; 3: López de Luchi *et al*., 1999; 4 López de Luchi *et al*., 2005, 5 Varela *et al*., 2005.

UNIT	ROCK TYPE	Rb/Sr_{WR} isochrone	U/Pb_{Zr}	K/Ar_{Amph}	K/Ar_{Ms}	K/Ar_{Bt}	Ref
CF	At Río Chico area (Río Negro province)	377 ± 33					1
		362 ± 10					1?
	Ms-Grt leucogranite				261 ± 6		2
	Bt-Ms schist at La Angostura				262 ±6		4
	Leucogranite at Cdon.Chacay Huarruca		302 ±39				5
TT	Diorite		286 ±13	250 ±16			5
MCG	HTG	325 ±16				326 ±12	3
						318 ±10	
						250 ±5.3	4
			273 ± 2			254 ± 9	5
	CMG	302 ± 20				306 ±10	3
							5
						237 ± 5	4
						230 ± 5	4
	NG				299 ± 11		3
	Pegmatite in NG				265 ± 6		4

Table 2: New K-Ar mineral ages for selected samples of the Paleozoic rocks of Río Chico-Sierra de Mamil Choique area.

Sample	Spike [No.]	K2O [Wt. %]	40 Ar * [nl/g] STP	40 Ar * [%]	Age [Ma]	2s-Error [Ma]	2s-Error [%]
C7-Biotite.	3499	9,29	69,87	96,22	219,3	4,6	2.1
Mch88-Biotite.	3492	8,92	66,83	95,83	218,5	4,7	2.2
MCH52 Muscovite.	3496	11,12	91,54	98,41	238,7	5,3	2.2

Table 3: Summary of structural/metamorphic/magmatic events in the Río Chico-Mamil Choique area, with absolute time constraints provided by already published and new geochronological data

DEFORMATION	STRUCTURE	METAMORPHIC//MAGMATIC EVENTS	AGES (Ma)
		Dykes and stocks (Gastre Suite magmatism?)	ca 220
D4	Brittle F4		239 ± 5
		NG emplacement	ca. 265 ± 6
D3	Ductile F3, shear zones, mylonites	**HTG** (and **CM** ?) emplacement	272 ± 2
		TT emplacement	286 ± 16
D2	Penetrative S2	Metamorphic peak in **CF**	335-300
D1	Relic S1		

Nevertheless, both magmatic and metamorphic mineral assemblages indicate mid-crustal levels for the MCG emplacement at Rio Chico-Sierra de Mamil Choique (Cerredo and López de Luchi, 1997, 1998, López de Luchi and Cerredo, subm.), whereas the Permian Yancamil Granite is emplaced at upper-crustal levels in Sa. de Calcatapul (von Gosen and Loske, 2004).

D3 controlled the emplacement of the MCG (Cerredo and López de Luchi, 1998, López de Luchi et al., 1999). The 265±6 K-Ar muscovite age of the undeformed pegmatite of the NG (López de Luchi, et al., 2005) is slightly younger than the U-Pb age of 272 ±2.2 Ma for the HTG (Varela et al., 2005), which may reflect the elevated closure temperatures for large muscovite booklets (Steenken et al, subm and references therein). Therefore the HTG and the NG are roughly coeval and high-temperature D3 deformation is then bracketed between 272-265 Ma in the Sierra de Mamil Choique.

The lack of penetrative deformation in the NG suggest that D3 is probably closer in time to the age of the HTG.

Biotite cooling ages for the western Sierra de Mamil Choique (Table 1) indicate that the granitoids were cooled down to ~300ºC by Early-Middle Triassic. The new Late Triassic biotite cooling ages for dykes of porphyric granites in the CMG facies are interpreted as a distinct magmatic event which could be related to the magmatism of the Batolito de la Patagonia Central (Rb/Sr isochron age of 220±3Ma, Rapela et al., 1992).

Pankhurst et al (2005) suggested that a part of the MCG could have been emplaced after the Gondwanide collision probably related with a process of slab-break off.

Our results together with the available data for the SW sector of the MNP (Table 3) indicate that a penetrative D3 deformation event occurred between 272-265 Ma controlling the emplacement of the MCG and affecting both S2 foliation and the TT, both in a trajectory of decompression. This interval constrains the end of the ductile deformation at upper greenschist facies. D2, the deformation that is associated with the peak metamorphic conditions is bracketed between 335-300 Ma. The D4 event might be assigned to the Triassic, a time in which the crust of the NPM is at more brittle conditions as may be documented by the inferred deformation induced resetting of the muscovite age of the fine grained leucogranite that is emplaced in the CF. The Late Triassic cooling age of the porphyric granitoids intruding CMG indicate that they would be related with the Batolito de la Patagonia Central. Therefore the Early-Middle Permian magmatic event may represent the transition to the regional Late Permian-Triassic extension. In a very regional perspective the D3 event could be correlated with the San Rafael phase

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RESUMEN

El basamento prejurásico del borde occidental del Macizo Norptagónico está integrado por complejo ígneos y metamórficos cuya edad está acotada entre el Devónico y el Triásico. En el sector sudoccidental del MNP, el basamento metamórfico es la Formación Cushamen (FC) mientras que los granitoides más antiguos fueron agrupados como Granitoides Mamil Choique (GMC). Este conjunto es intruido por granitoides indeformados pérmico tardíos a triásicos. En la FC se reconocieron dos fases de deformación D1 y D2 acompañadas por desarrollo de foliación (S1-S2). Las condiciones de pico metamórfico fueron coetáneas con S2-D2. Dos eventos deformativos posteriores (D3 y D4) afectaron tanto al basamento metamórfico como a las unidades intruidas en él. D2 se halla acotado entre 335-300 Ma. D3 tuvo lugar entre 272-265 Ma controlando el emplazamiento de GMC y afectando S2 y las tonalitas emplazadas en ella ambas en una trayectoria decompresiva. Este intervalo indica entonces el fin de la deformación dúctil de alta temperatura. El evento D4 se asigna tentativamente al Triásico, una época en la cual la corteza del MNP se hallaba en condiciones frágiles como lo documenta la edad muscovita obtenida en un granitoide intruido en FC. La edad triásica tardía de granitoides porfíricos que intruyen GMC indicarían que pueden relacionarse con el Batolito de la Patagonia Central. En consecuencia se puede considerar que el evnto mgmático de edad pérmica temprana a media puede representar la transición a la extensión regional pérmica tardía a triásica.