NOTA GEOLOGICA

GEOCHRONOLOGY OF THE PURILACTIS FORMATION, NORTHERN CHILE: AN INSIGHT INTO LATE CRETACEOUS/EARLY TERTIARY BASIN DYNAMICS OF THE CENTRAL ANDES

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RESUMEN

La Formación Purilactis, de la Precordillera de Antofagasta, se depositó, durante el Cretácico Superior-Paleoceno, en una cuenca de antepaís desarrollada al este de la Cordillera de Domeyko, elevada durante un evento regional de deformación compresiva, en el Cretácico 'medio'. El relleno de la Cuenca de Purilactis está formado por más de 3,5 km de rocas sedimentarias continentales, que se organizan en varias secuencias cuya granulometría aumenta hacia el techo ('coarsening-up sequences'). Estas son el resultado de la propagación hacia el este de sistemas de abanicos aluviales, probablemente relacionados con movimientos de fallas inversas (thrusts), en zonas más occidentales. Períodos de quietud tectónica durante la acumulación de Purilactis, estuvieron acompañados por la extrusión de un flujo de lava andesítica, observado en la parte media de la sección expuesta de la formación. Su datación radiométrica ^{40}Ar/^{39}Ar indicó 64 Ma (aunque el error analítico es grande), correspondiente al límite cretácico-terciario. La cuenca de Purilactis fue tectónicamente invertida durante la fase compresional Incaica del Eoceno y sirvió, en parte, como fuente de aporte de detritos para las secuencias sedimentarias oligo-miocenas del Grupo Paciencia (formaciones Tambores y San Pedro), ubicado más al este.

Palabras claves: Geocronología, Cretácico-Terciario, Formación Purilactis, Antofagasta, Chile.

INTRODUCTION

The sedimentary record of the Triassic-Recent Andean cycle as developed in northern Chile includes several kilometres thickness of continental red beds. Such sequences are problematical worldwide with respect to defining chrono-stratigraphic correlation and thus histories of basin formation, rates of deposition and inversion/unroofing.

The Purilactis Formation of Antofagasta Region, Chile, crops out in the Cerros de Purilactis, between 22°30'-22°55'S and 68°15'-68°55'W, which form a northward extension to the Cordillera de Domeyko and a western boundary to the northern part of the Salar de Atacama (Fig. 1). The Purilactis Formation was first described by Brüggen (1934, 1942, 1950). Subsequent work by Dingman (1963, 1967) defined a type section through the formation, which has a stratigraphic thickness of over 3.5 km, exposed within an asymmetric, NE-SW trending synclinal structure. Dingman (*op. cit.*) also distinguished the Purilactis Formation from southerly, adjacent red beds of the assumed Jurassic Tonel Formation on the basis of structural contacts and the presence of dykes in the latter unit.

This view was challenged by Ramírez and Gardeweg (1982) who assigned the Tonel sediments to the Purilactis Formation, a thesis supported by Marinovic and Lahsen (1984). This modification was

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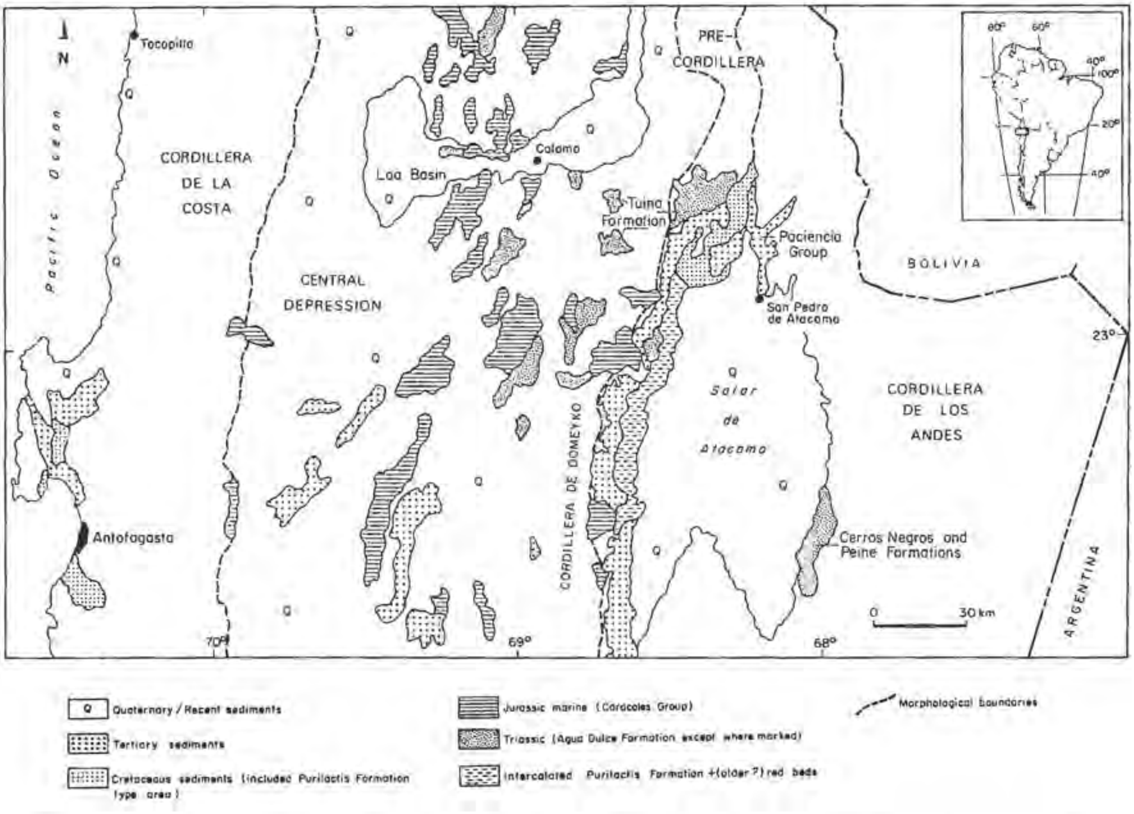

FIG. 1. Regional geology of Antofagasta Region, Chile. Inset shows the position of the area within the Central Andes. The Purilactis Formation forms part of the Precordillera to the west of the Salar de Atacama.

significant as, if correct, it extended the outcrop area by some 80 km along strike to the south (Fig. 1). Current studies by Charrier and Reuter (1988, personal commun.) and ourselves are addressing the nature of the interelationship between these two formations. Most workers now agree that the Purilactis Formation does extend southwards from the original type area, along the western margin of the Llano de La Paciencia (Fig. 1).

Some workers believe the Tonel Formation to represent a fine grained member of the Purilactis Formation (Charrier and Reuter, personal commun.). Our current understanding of this structurally complex area is that an older red bed sequence is separated from the Purilactis Formation by an unconformity which has subsequently been folded and thrusted. Clearly more detailed studies are required to fully resolve the stratigraphy in this area.

The Purilactis Formation is itself overlain with angular unconformity by Oligocene continental sediments of the Paciencia Group in the east (Hollingworth and Rutland, 1968; Flint, 1985).

LITHOSTRATIGRAPHY OF THE PURILACTIS FORMATION

In the Cerros de Purilactis, the exposed basin-fill includes four coarsening-upward megasequences (Hartley *et al.*, 1988). The type section of Quebrada Seilao exposes a lower, 900 m thick, coarsening-upward unit, overlain by some 350 m of aeolian dune sandstones and reworked dune (fluvial) sand bodies. These strata are in turn overlain by the Purilactis lava which forms a prominant topographic legde (Fig. 2) in the Quebrada Seilao section. The lava is 43 m thick with some 6 m of basal volcanic breccia; its stratigraphic association with the aeolian and reworked aeolian sandstones may signify a brief period of net extension during the life of the Purilactis basin. The extrusive nature of the igneous body is proven by the presence of a lower breccia member, the conformable nature of the unit with subjacent/superjacent beds and the presence of a highly weathered, subaerially exposed upper surface.

The lava is overlain by some 2 km thickness of stacked, coarsening upward alluvial fan progradational cycles (Hartley *et al.*, 1988), which may represent a sedimentological response to renewed thrusting/source area advance from the west.

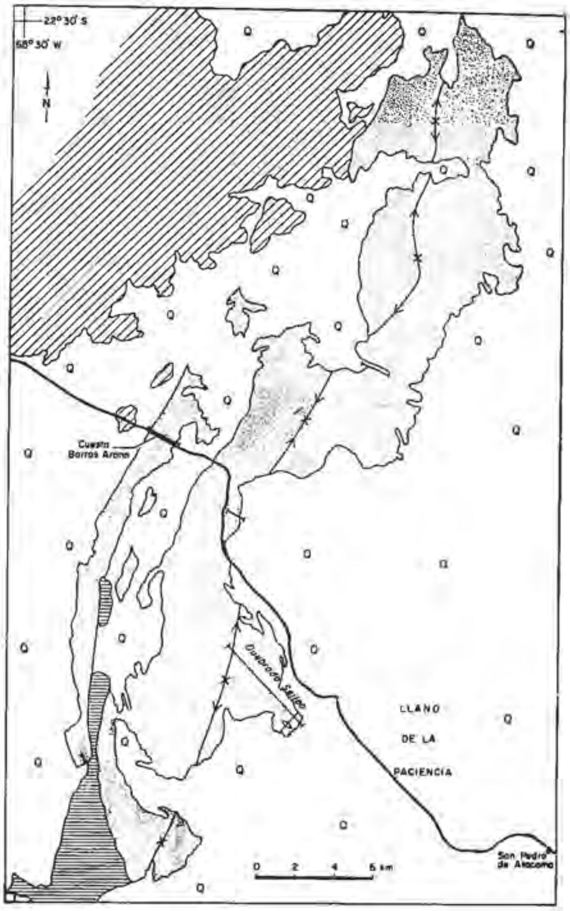

FIG 2. Field relations of the Purilactis lava, Quebrada Seilao. View looking southwest. Lava is approximately 40 m thick.

GEOCHRONOLOGY

LAVA PETROGRAPHY

The studied lava is a dark grey porphyritic andesite with phenocrysts of plagioclase feldspar and clinopyroxene (Fig. 3). Thin section examination shows the rock to be highly altered, with feldspars weathered to clay minerals and a secondary matrix of clay minerals. Thus it was extremely difficult to extract intact crystals of datable minerals. Finally a clinopyroxene crystal was hand-picked for analysis. Pyroxenes are not the most commonly used mineral in Ar-Ar dating but their experimental behaviour and viability for this method are well documented (McDougall and Harrison, 1988).

EXPERIMENTAL DETAILS

Analyses were carried out in the geochronological laboratory of the University of Leeds. Full details of the irradiation and argon analysis used at Leeds are to be found in Parsons *et al.* (1988). The hornblende samples were purified using a Franz magnetic separator and the final 100% purity of the *c.* 75 mg samples were checked under a binocular microscope. The samples were irradiated at A.W.R.E. (England) in the Herald reactor. International standard minerals, HBGR hornblende, LP6 biotite together with the Leeds laboratory standard hornblende FY12a were used as 'J' monitors for the irradiation (Roddick, 1983). Errors quoted on the original heating steps are analytical errors while errors (in Ma) quoted on the total fusion ages include the 'J' value errors (Tables 1a, b).

RESULTS

Tables 1a, b show the results of a mass spectrometer run and repeat run on a clinopyroxene crys-

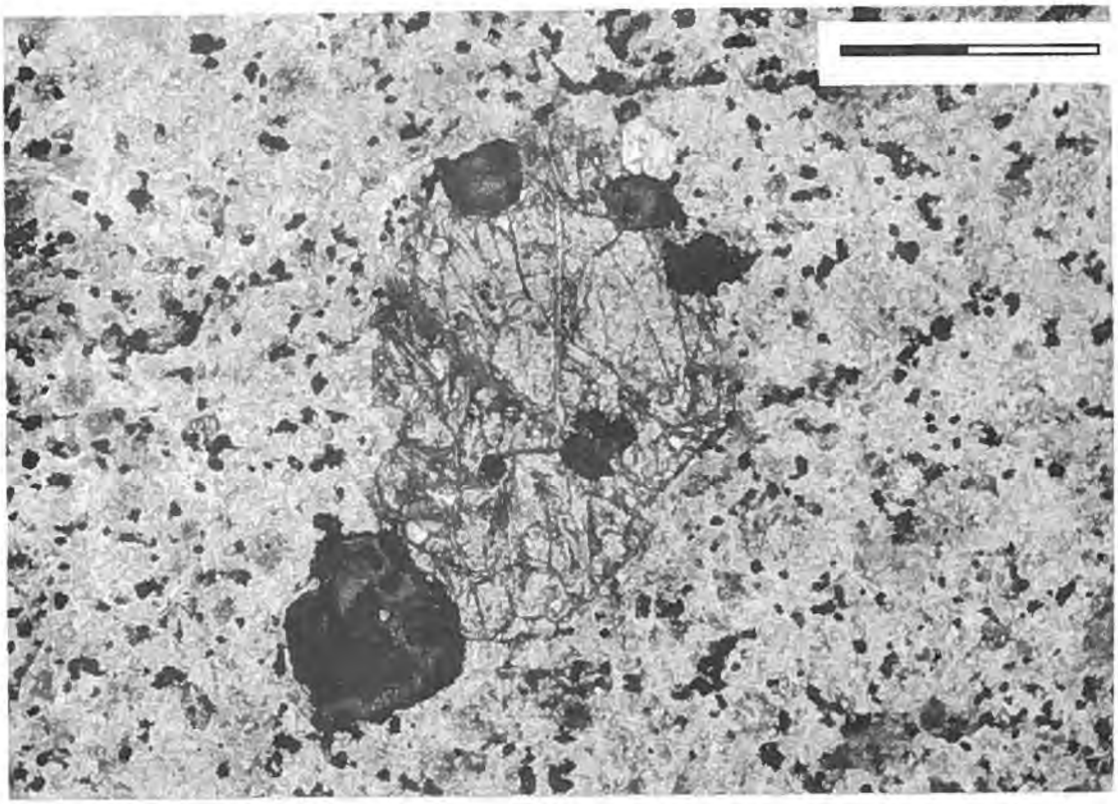

FIG. 3. Thin section photomicrograph of the Purilactis lava showing clinopyroxene phenocryst. Note the highly altered state of the matrix which consists of calcite, plagioclase feldspars replaced by clay minerals and opaque phases. Scale bar = 0,5 mm. Plane polarised light.

tal. The first two temperature steps on the rerun (run 890) are better than the original run because the blanks are lower and lower temperature steps were taken (Fig. 4). These conditions resulted in a lower analytical error and a better representation of the age of the lava. Further inspection of the data (Tabla 1a, b) shows that the 4th step can be ignored in both runs as the Ca/K ratio reveals excess Ca (^{37}Ar). The true error in this case must be higher because of the small Ca volumes measured and the shape of the spectrum (Fig. 4).

Interpretation of our data indicates that the Purilactis lava was erupted onto a surface of lower Purilactis strata at 64 ± 10 Ma, during the Maastrichtian-Palaeocene periods.

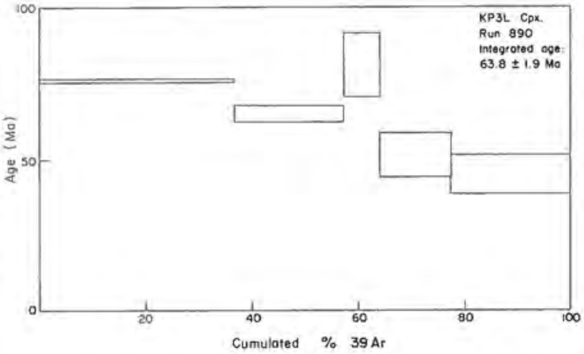

FIG. 4. Diagram of the spectra for Run 890, showing the cumulative percentage of ^{39}Ar released per heating step and the resultant integrated age.

DISCUSSION

Stratigraphic relations and the presence of clasts in the Purilactis Formation containing Upper Jurassic marine fossils were used by Brüggen (1934; 1950) to assign a Cretaceous age to the Purilactis Formation. More recent regional geological syntheses have delineated episodes of major

TABLE 1. ARGON^{40}/ARGON^{39} GEOCHRONOLOGY ANALYSES OF A CLINOPYROXENE MINERAL FROM THE PURILACTS FORMATION LAVA.
(Isotope values in Vol x 10^{-9} cc)

a. Run 889, KP3L. Cpx, Chile. Weight = 0.07096 gms. J. value = 0.002845 ± 1.0%.
Atmos.$^{40/36}$ = 288.3 ± 0.2. Sensitivity = 0.780 *10^{-7} cc/volt.

Temp.(°C)	^{39}K	^{37}Ca	^{38}Cl	Blank	Ca/K	*$^{40/39}$K	%Atm^{40}	Age(Ma)	Error%	%^{39}Ar
750.000	0.875	0.361	0.007	0.000	0.821	16.184	96.200	81.210	20.230	54.500
910.000	0.164	0.077	0.001	0.000	0.904	14.476	65.700	72.810	5.250	10.200
1050.000	0.218	0.960	0.000	0.000	8.774	9.978	64.200	50.500	6.220	13.500
1380.000	0.349	103.049	0.001	0.058	87.329	9.362	71.400	47.420	9.070	21.700

Integrated values

·$^{40/39}$K: 13.686; Age: 68.91 Ma. Errors: Analytic 11.32 and J 11.40 Ma; Wt % K: 0.113 *40 3.10 x 10^{-7} cc/gm

b. Run 890, KP3L. Cpx, Chile. Weight = 0.07179 gms. J. value = 0.002845 ± 1.0%
Atmos.$^{40/36}$ = 288.3 ± 0.2. Sensitivity = 0.780 *10^{-7} cc/volt.

Temp. (°C)	^{39}K	^{37}Ca	^{38}Cl	Blank	Ca/K	*$^{40/39}$K	%Atm^{40}	Age(Ma)	Error%	%^{39}Ar
625.000	0.568	0.234	0.002	0.000	0.821	15.073	37.400	75.750	0.610	36.600
750.000	0.322	0.156	0.001	0.000	0.964	12.841	87.600	64.730	2.640	20.700
860.000	0.106	0.067	0.001	0.000	1.0252	16.107	62.500	80.830	10.490	6.800
1010.000	0.210	0.874	0.001	0.058	8.290	10.180	66.800	51.510	7.030	13.500
1340.000	0.347	106.089	-0.001	0.060	609.179	8.911	72.000	45.170	6.230	22.300

Integrated values

*$^{40/39}$K: 12.643; Age: 63.75 Ma. Errors: Analytic 1.92 and J 2.29 Ma; Wt % K: 0.108 *40 2.73 x 10^{-7} cc/gm

folding during the middle Cretaceous and late Eocene in northern Chile (Coira *et al.*, 1982). The Purilactis Formation must be pre-late Eocene but its age relative to the middle Cretaceous uplift and depositional hiatus is not clear from stratigraphic relations alone. Our radiometric date from the Purilactis lava allows a more precise age determination of the sequence and suggests that the Purilactis Formation may be a diachronous unit of Upper Cretaceous to Palaeocene age. Thus the Purilactis basin was formed following regional middle Cretaceous compressive deformation and emergence of the Cordillera de Domeyko as a major thrust belt (Turner *et al.*, in press). The basin-fill was inverted during the late Eocene Incaic phase of regional deformation and formed a partial provenance area for the Oligo-Miocene continental sediments of the Paciencia Group (Tambores and San Pedro formations) to the east (Dingman, 1963; Flint, 1985).

It has been suggested that the Purilactis basin was a sub-basin of the Salta Group basin of northwestern Argentina (Salfity *et al.*, 1985), based on some sedimentological similarities and stratigraphic correlations. Marquillas and Salfity (1988) suggested that the basins were partially separated by the Huaytiquina swell in the area of the present High Andes. Our sedimentological (Hartley, 1987; Hartley *et al.*, 1988) and geochronological studies of the Purilactis Formation indicate that although the basin may be synchronous with the Salta Basin, it formed as an intermontane basin, genetically linked to the emergence of the Cordillera de Domeyko thrust belt. The exact origin of the Salta basin is not clear, but the presence of basaltic lavas within the Salta Group (Marquillas and Salfity, 1988) suggest a tensional crustal regime, recently interpreted as a rift setting (Grier *et al.*, 1988).

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