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THE "K-T" COMPRESSIVE DEFORMATION EVENT IN NORTHERN CHILE (24-27º S)

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INTRODUCTION

Detailed regional mapping of the Central Depression and Precordillera between El Peñón and Inca de Oro (24-27º S), in combination with the accumulation of large geochronological (K-Ar, Ar/Ar and U/Pb) and geochemical databases, have been carried out by SERNAGEOMIN over the last 10 years (Table 1). During these studies, a regional compressive deformation event was recognised, which produced a marked angular unconformity between uppermost Cretaceous sequences and the overlying Paleocene volcanic successions. This unconformity was initially described by Cornejo et al. (1997) in the El Salvador area, and assigned an age of latest Cretaceous to earliest Paleocene, based on K-Ar and U-Pb data for the overlying Upper Paleocene volcanic rocks. At this time, no high quality geochronological data were available for the underlying deformed Cretaceous rocks (Llanta formation; Frutos et al., 1975).

In this paper we describe field relations, supported by new geochronological data for the underlying Cretaceous sequences and overlying Paleocene successions, spread over a 300 km long segment of the Central Depression, which precisely define the age of this deformation phase.

UPPERMOST CRETACEOUS SEQUENCES

In the Central Depression between Inca de Oro and El Peñón, a series of deep, narrow, north-south trending extensional basins has been recognised, within which, thick uppermost Cretaceous continental volcanic and sedimentary sequences were accumulated (Quebrada Seca and Llanta formations to the south and Quebrada Mala formation to the north). These basins are bounded by normal faults to the east and west, and thinner, dominantly volcanic sequences are present outside the basins on both sides (Cerro Los Carneros strata; 26º30'S, El Estanque strata; 25º15'S, Pampa Mirador rhyolites (25º30' S), and the ignimbrites of Cerro Los Trigos-Cerro Dominador; 24-25º S).

In the Inca de Oro area a late Upper Cretaceous plutonic complex (La Finca and La Tuna plutons) intrudes both Upper Jurassic to Lower Cretaceous sequences and the lower part of the Llanta formation. This complex comprises gabbros, diorites, monzonites and monzogranites, and is considered to represent part of a discontinuous calcalkaline plutonic arc, empalaced to the west of the Upper Cretaceous basins. Similar plutonic complexes intrude the Cerro Los Trigos Ignimbrites to the NW of El Peñón.

BASIN-FILL SEQUENCES

The Quebrada Seca formation (Muzzio, 1980) is recognized in the La Guardia area (Iriarte et al., 1999). This unit has a maximum thickness of 1000 m and comprises a lower member of sandstones, conglomerates, volcanic breccias, lavas and ignimbrites, and an upper member, dominated by trachyandesite and basaltic andesite lavas.

The Llanta formation (Frutos et al., 1975) is recognised from Inca de Oro (26º45') to the Altamira area (25º30' S). This unit comprises a heterogeneous succession, with thicknesses of up to 2000 m, of continental volcanic and sedimentary rocks, which unconformably overlie Jurassic to Lower Cretaceous units (e.g. Cornejo et al., 1993).

Close to basin-bounding faults, thick sedimentary breccias and conglomerates are present, which contain dominantly andesitic to rhyolitic clasts up to 1 m in size. These units pass upwards, and horizontally towards the basin axes, into fluvial and lacustrine sandstone, siltstone and mudstone sequences. In many areas, thick basaltic to andesitic volcanic intercalations are present both in the base and the top of the formation. Additionally, thin but widespread rhyolitic to dacitic ignimbrite flows are recognised in different levels of the formation.

The Venado formation (Sepúlveda & Naranjo, 1982; Iriarte et al., 1996) crops out along the western margin of the Central Depression in the Carrera Pinto geological map (27º - 27º15' S). Based on new geochronological data, we suggest that the lower and middle continental sedimentary units of the Venado formation are of Upper Cretaceous age, and equivalent to the Llanta formation.

Between Altamira (25º30' S) and El Peñón (24º20' S), the Upper Cretaceous rocks are buried under Paleocene to Eocene volcanic sequences. From El Peñón northwards, the basin-fill sequences are again exposed, where they comprise continental volcanic (lavas, breccias and ignimbrites) and sedimentary (conglomerates and epiclastic sandstones) rocks, assigned to the Quebrada Mala formation (Montaño, 1976) in the Pampa Union area (23º - 23º30' S) by Marinovic y García (1999).

BASIN-SHOULDER VOLCANIC UNITS

On both the eastern and western sides of the Upper Cretaceous basins, a series of volcanic units has been recognised, which are contemporaneous with the basin-filling sequences. These units have been described by several workers and assigned a number of local names.

The Cerro Los Carneros strata (Muñoz, 1984) have been described along the eastern side of the Central Depression, from 26º - 28º S (Cornejo et al., 1998; Iriarte et al., 1996; 1999) as a sequence over 1000 m of basaltic to andesitic lavas with minor volcanic breccias and ignimbrite intercalations. On the western boundary of the basin at this latitude, Iriarte et al. (1996) described a basaltic lava sequence (Sierra La Dichosa lavas; Arévalo, 1994) which probably represent an equivalent unit.

The Pampa Mirador rhyolites (Naranjo y Puig, 1994) comprise a series of small outliers of highly welded, crystal-rich ignimbrites, which unconformably overlie the Paleozoic to Jurassic units between Aguas Verde and Altamira (25º-26º S) on the western side of the Central Depression. A similar ignimbrite unit on the eastern side of the Central Depression overlies Upper Jurassic rocks and was denominated "El Estanque strata" by the same authors. The same ignimbrites have been recognised on both sides of the Central Depression during recent mapping carried out by SERNAGEOMIN. The most representative outcrops of this unit occur on the western side of the Dominador fault zone, between Cerro Los Trigos (24º45' S) and Cerro El Arbol (24º15' S). Here, the ignimbrite unit overlies Triassic to Jurassic rocks and is overlain unconformably by Paleocene volcanic successions. Similarly, on the eastern side of the Central Depression, these ignimbrites are exposed in Cachinal de la Sierra District (25º S) and have been recognized as far north as Pico de Oro 23º30' S (Marinovic et al., in prep.). In this presentation, we refer to these units collectively as the Cerro Los Trigos ignimbrites.

GEOCHRONOLOGY OF LATEST CRETACEOUS UNITS

a) Llanta and Quebrada Seca formations

The age of the Llanta formation has been defined using direct U/Pb and Ar/Ar analyses of volcanic intercalations (Table 1), with further constraints obtained from K-Ar ages of the plutons which intrude this unit. Three zircon U/Pb analyses for an ignimbrite intercalation in the northern limit of the El Salvador sheet gave two ages of 76.8 ± 0.1 Ma and another of 76.7 ± 0.05 Ma. In the Quebrada de Chañaral Alto (Inca de Oro geological map), a fluidal rhyolite clast in the basal sedimentary breccias of the Llanta formation gave a zircon U/Pb age of 80.2 ± 0.3 Ma. Another rhyolitic clast in the overlying sandstone unit gave an age of 69.8 ± 0.2 Ma. In the Sierra Caballo Muerto and Sierra Miranda, El Salvador area, three hornblende Ar/Ar ages of 68-72 Ma were obtained for andesitic breccias. In the northeastern limit of the Carrera Pinto geological map (La Puerta), a hornblende Ar/Ar age of 65.7 ± 0.9 Ma was obtained for an andesitic breccia assigned to the uppermost part of the Llanta formation in this area. A zircon U/Pb age of 65.2 ± 0.1 Ma was obtained for a welded ignimbrite slightly higher in the sequence, nearby in El Salto. No high quality geochronological data are available for the Quebrada Seca formation. However, hornblende K-Ar age of 72 ±9 Ma for a tuff intercalation near the base of the formation, and a biotite K-Ar age of 68±2 Ma for an andesite porphyry, which intrudes the lower member, indicate a similar age range for this formation (Iriarte et al., 1999). No direct geochronological analyses are available for the lower and middle sedimentary units of the Venado formation, but new Lower Paleocene ages obtained for the upper volcanic unit (see below) and for the Cachiyuyo Pluton (63-61 Ma) which intrudes the entire formation, suggest that the lower and middle units are probably of Upper Cretaceous age and equivalent to the Llanta formation.

Based on these results, an age range of 80-65 Ma (Campanian-Maastrichtian) is assigned to the Llanta formation and the equivalent Quebrada Seca formation and lower and middle units of the Venado formation.

b) Cerro Los Carneros strata

The age of this unit has been defined using K-Ar analyses of intercalated ignimbrites and lavas (Table 1), and of several intrusions which are emplaced into this sequence. The most reliable geochronological data which are available from the La Guardia, Carrera Pinto, Inca de Oro and Salar de Maricunga geological maps (Iriarte et al. 1999; 1996; Matthews et al. in press; Cornejo et al., 1998), comprise biotite and hornblende K-Ar ages of lavas and ignimbrites, which range from 68 to 65 Ma. In the Salar de Maricunga area this unit is intruded by several Upper Cretaceous plutons with biotite and hornblende K-Ar ages of 64 to 67 Ma. These results indicate an age range of 70-65 Ma for this unit (Maastrichtian).

c) Cerro Los Trigos Ignimbrites

This unit has been dated using K-Ar and Ar/Ar analyses, both of the ignimbrites and of plutons which intrude them. Published and new biotite K-Ar data from a number of localities range from 76 to 71 Ma, in combination with a sanidine Ar/Ar age of 72.9±0.7 Ma, indicate a Campanian age for this unit (Table 1).

d) Upper Cretaceous plutons

Biotita K-Ar ages of plutonic complexes to the west of the Upper Cretaceous basins in the Inca de Oro and El Peñón areas, range from 70-65 Ma.

COMPRESIONAL EVENT AND SYNTECTONIC MAGMATISM

The Upper Cretaceous basins were inverted prior to the deposition of the Paleocene volcanic sequences, forming a marked angular unconformity. This event affected mainly the basin-fill sequences and the basin-shoulder sequences of the eastern side. The less competent strata, notably the fluvio-lacustrine sandstone units were deformed into an eastward-verging fold and thrust belt, which developed along the eastern margin of the basin, between Inca de Oro and El Salvador (27-26º S). The basin-bounding normal faults were reactivated as high-angle reverse faults (Matthews et al., in press), while lower-angle breakouts developed in front of these, carrying slivers of Jurassic rocks over the basin-shoulder sequences (e.g. Agua Amarga fault). During this event, the Sierra Fraga block was first uplifted along the La Ternera Fault system. Many of these faults were reactivated again during the mid-Eocene Incaic deformation phase (Tomlinson et al., 1993). The basin-shoulder sequences suffered less intense deformation, although low-amplitude folds, minor faults and gentle regional tilting were developed mostly along the eastern side of the basins. The latest Cretaceous plutonic complexes were uplifted and denuded on the western side of the basins. In Inca de Oro area, Upper-Paleocene volcanic sequences lie directly upon these intrusions.

To the south of Inca de Oro, a syntectonic dioritic pluton was emplaced along a NE-trending strike-slip fault with development of mylonites along the fault contact. K-Ar and Ar/Ar ages for these plutons range from 65 to 62 Ma, providing a direct measurement of the age of the deformation event in this area.

South of Inca de Oro, in Portezuelo Chimberos (27º S), the Lower Paleocene volcanism is represented by the upper unit of the Venado formation (Sepúlveda y Naranjo, 1982), which comprises trachyandesite lavas with intercalated rhyodacitic ignimbrites, and fluvial sandstones and conglomerates. The conglomerate intercalations contain clasts of Jurassic basalt lavas and jasper amygdale fill derived from the nearby Sierra Fraga block to the east, confirming that this block was first uplifted in the “K-T” deformation event. A slightly discordant zircon U/Pb age from a rhyodacitic ignimbrite gave an age of 63.7 ± 2.7 Ma, conchordant with a whole-rock K-Ar age of 62.5 ± 1.5 Ma obtained from a trachyandesite lava flow.

From Quebrada Doña Inés Chica (26º10’ S) northwards to the Catalina area (24º45’S) , syntectonic magmatism is represented by large extrusive dome complexes and associated block-

and-ash deposits and ignimbrites (eg. Pampa del Carrizo, Cerro Guanaco, Morros Blancos and Sierra del Toro complexes). This volcanic activity was focused along north-south trending fault systems, which represent the reactivated western margin of the Upper-Cretaceous basins. The most notable of these is the Catalina fault system, which controlled the emplacement of a line of domes extending from Cerro Guanaco, to the south, to Sierra del Toro to the north. This volcanic activity was characterised by crystal-rich andesitic to dacitic magmas containing amphibole, pyroxenes and biotite.
These complexes lie unconformably over the Upper Cretaceous sequences. In the Quebrada del Carrizo (26º S), basal fluvial sediments contain an intercalated ash layer with a hornblende Ar/Ar age of 62.2 ± 1.8 Ma. These sediments are overlain by an ignimbrite flow (hornblende Ar/Ar age of 61.5 ± 1.8 Ma), followed by block-and-ash flow deposits of the Pampa del Carrizo Complex, (hornblende Ar/Ar age of 62.0 ± 0.6 Ma).

Towards the north, along the Panamerican Highway, between Pampa Callejas and Salitrera Flor de Chile (25º05'S-25º15' S), basal rhyodacite ignimbrites unconformably overlie the Upper Cretaceous Cerro Los Trigos Ignimbrites. Three biotite and hornblende K-Ar ages in these basal flows range from 61-65 Ma. These ignimbrites are overlain by the Sierra del Toro dome complex and its associated block-and-ash deposits.

These field relationships and geochronological data constrain the age of the "K-T" deformation event to 65-62 Ma (lowest Paleocene) (Table 1).

UPPER PALEOCENE-LOWER EOCENE VOLCANIC SEQUENCES.
Both the Upper Cretaceous and Lower Paleocene sequences are unconformably overlain by Upper Paleocene to Lower Eocene volcanic units. The unconformity between the Lower and Upper Paleocene is mainly the result of onlap a pre-existing topography related to the formation of the dome complexes although in some locations it is possible to identify tectonically-induced angular unconformities. This relationship indicates that the majority of the Lower Paleocene volcanic products were erupted DURING the "K-T" event i.e. they are syntectonic.

The Upper Paleocene-Lower Eocene volcanic sequences comprise large-volume silicic ignimbrite flows and rhyolitic dome complexes associated with collapse calderas and basaltic to trachytic lava piles which represent extracaldera and post-collapse intracaldera volcanism. Minor continental sedimentary units, such as fluvial sandstones and alluvial conglomerates, commonly occur as intercalations within the volcanic piles. The volcanic sequences fill discontinuous transtensional basins, which formed over the original locus of the Upper Cretaceous basins, reactivating many of the original bounding normal fault systems and forming NE-trending transtensional faults. The collapse calderas nucleated mainly in "corner zones" where N-S trending normal faults and NE-trending transtensional faults intersected. Calderas were commonly of trapdoor (e.g. El Salvador caldera, La Banderita and San Pedro de Cachiyuyo calderas, Inca de Oro) or horst-and-graben (e.g. El Peñón area) types, indicating a clear tectonic control on magma chamber formation and collapse mechanisms.

The Upper Paleocene to Lower Eocene volcanism is organised into distinct segments along the Central Depression, with different modes of volcanic activity and differences in the dominant magma types occurring in different areas. Additionally, the timing of initiation of magmatism in the Upper Paleocene varied slightly from one area to another. The following segments have been recognised, from south to north;

INCA DE ORO – EL SALVADOR SEGMENT (26º - 27º S).
In Inca de Oro and El Salvador, the Upper Paleocene to Lower Eocene volcanic activity was centred on medium sized collapse calderas, with lesser volcanic activity occurring outside these structures. The oldest of these calderas is the El Salvador Caldera, whose basal extracaldera ignimbrites and intracaldera flow units have been dated by Ar/Ar (biotite and sanidine) at 60-59 Ma (Table 1). These results confirm the early U/Pb and K-Ar analyses obtained by Cornejo et al. (1997). The Indio Muerto rhyolitic dome, which cuts these ignimbrites, is slightly younger, with a zircon U/Pb age of 58 ± 2 Ma. The andesitic lava pile, which overlies the extracaldera ignimbrites in Los Amarillos, is of a similar age, as is confirmed by a hornblende Ar/Ar age of 57.8 ± 0.6 Ma, obtained in a dacitic porphyry which intrudes these lavas.

The La Banderita Caldera, to the SE of Inca de Oro, contains a pre-collapse sequence of trachyandesite lavas, overlain by syn-collapse welded ignimbrites. These, in turn, are cut by a complex of post-collapse dacitic to rhyolitic domes and ring dykes, emplaced along the outer ring fault. To the north, an extracaldera sequence (Quebrada Vásquez strata) comprises andesite lavas, continental sandstones and conglomerates, and extracaldera ignimbrites of La Banderita Caldera. U/Pb zircon ages for the intracaldera (57.7 ± 0.5 Ma) and extracaldera (56.6 ± 0.1 Ma) ignimbrites, biotite Ar/Ar ages for the post-collapse domes (55.6 ± 0.6 Ma, 55.9 ± 1.2 Ma), and a U/Pb zircon age obtained for the rhyolitic ring intrusion (55.4 ± 0.1 Ma), indicate that this centre is slightly younger than the El Salvador Caldera (Table 1).

Volcanic activity in this area continued into the Lower Eocene, with the formation of the San Pedro de Cachiyuyo Caldera; a trapdoor collapse structure containing at least 600 m of welded ignimbrites with a sanidine K-Ar age of 53.5 ± 2.1 Ma. The latest activity was centred on the Llano San Pedro structure; a volcanotectonic depression containing at least 200 m of andesitic lavas and bounded by a semicurcular fault to the east. A whole rock K-Ar age of 51.8 ± 1.3 Ma was obtained for one of these lavas (Table 1).

ALTAMIRA -EXPLORADORA SEGMENT (25º15’ – 26º S)
To the north of the El Salvador geological map, the Upper Paleocene to Lower Eocene volcanic activity was centred on wide shield volcano structures. The volcanic products comprise trachyandesites , andesites, basalts and scarce rhyolitic to rhyodacitic welded ignimbrites. No collapse caldera structures have been recognised in this segment. The earliest volcanic products comprise black welded rhyolitic to rhyodacitic vitrophyres which lie unconformably upon Upper Cretaceous rocks and Lower Paleocene volcanic products. These vitrophyres have been dated in varios localities using biotite K-Ar analyses, with results ranging from 54-57 Ma. In the Pampa Rubia area (25º50’ S), an extensive shield volcano produced trachyandesitic to andesitic lavas, which in part overlie the basal vitrophyres, and in other areas directly overlie the Upper Cretaceous Llanta formation. The basal lava flows of this volcanic centre have whole rock K-Ar ages of 57.5 ± 1.9 Ma and 57.3 ± 1.9 Ma, whereas a rhyolitic ignimbrite intercalated in the upper part of the sequence has a plagioclase Ar/Ar age of 53.5 ± 0.7 Ma (Table 1). To he north, a series of dominantly basaltic volcanic centres is present (Quebrada la Pólvora, Cerro Chicoteado, Cerro Corcovado, Pampa Negra). These centres have whole-rock K-Ar ages ranging from 55-51 Ma.

GUANACO-EL PEÑÓN SEGMENT (24º-25ºS)
In this segment the Upper Paleocene to Lower Eocene volcanic activity was centred in trapdoor calderas (El Soldado; Puig et al., 1988) and horst-and-graben collapse structures (El Peñón area). The eruption products were dominated by large-volume rhyolitic to rhyodacitic ignimbrite flows, intercalated andesitic and trachyandesitic lavas, and late rhyolite domes which were intruded along N-S trending normal fault arrays. In the southern part of the segment, the ignimbrites are overlain by basaltic lavas, which originated from the Pampa Negra volcanic centre.
Biotite K-Ar ages for the ignimbrites in various localities (range from 60-57 Ma). At El Peñón, a zircon U/Pb analysis of the mineralised rhyolite dome identified two populations with ages of 55.4 ± 0.2 Ma and 54.4 ± 0.2 Ma, while a biotite Ar/Ar age of 54.5 ± 0.6 Ma was obtained for the fresh southern part of the dome. In the El Soldado – Cachinal – Sierra Las Pailas area, a large number of biotite K-Ar ages ranges from 56-53 Ma (Table 1).

The geochronological data presented here indicate that Upper Paleocene volcanism in the southern and northern segments began at 60 Ma with the generation of large volumes of silicic ignimbrites. This activity continued until 57 Ma, after which the activity was dominated by smaller volumes of rhyolitic domes. In the central segment, the volcanic activity began at around 57 Ma and was dominated by more mafic volcanism, which continued until around 51 Ma. The caldera structures and later dome complexes were controlled by N-S extensional and NE – trending transtensional fault systems.

DISCUSSION
The Upper Cretaceous (80-65 Ma) extensional tectonic regime was interrupted by a short-lived but intense compressional event which lasted from 65-62 Ma ("K-T" compressional event). Syntectonic volcanism was amphibole-rich and dominated by andesitic to dacitic magmas. Extension was resumed at 60 Ma and was accompanied by the generation of large volumes of silicic magmas, erupted from caldera collapse structures. The extensional regime continued until at least 54 Ma and was associated with rhyolitic dome complexes and more mafic magmatism. The magmatism was organised into three main sectors, with more rhyolitic-dominated activity to the north and south, and andesitic to basaltic activity concentrated in the central segment.

The "K-T" compressional event is of a regional nature and has also been recognised in the Salar de Maricunga and Poterillos areas (Cornejo et al., 1998; Tomlinson et al., 1999). In both areas, there is a marked angular unconformity between the Upper Cretaceous Llanta formation and the overlying Upper Paleocene volcanic sequences. In the Pampa Union area (Marinovic & García, 1999), a marked difference in degrees of deformation is noted between the Upper Cretaceous Quebrada Mala formation, which is strongly folded, and the Upper Paleocene Cinchado formation, which is relatively undeformed. This difference is attributed by Marinovic & García (1999) to a tectonic inversion of the Quebrada Mala basin following 66 Ma, at which time the Sierra del Buitre fault, which probably represented a basin-bounding fault, was raectivated as a reverse fault. Cataclastic rocks along this fault have K-Ar ages of 64-57 Ma. In the Salar de Atacama region, Mpodozis et al. (in press), recognise a marked angular unconformity between the Tolola formation (70-65 Ma) and the overlying "Orange formation" (Paleocene-Lower Eocene). To the north of Calama, the Upper Cretaceous Cerro Empexa formation (U/Pb ages of 68.2 ± 0.4 Ma and 65.6 ± 0.4 Ma; Tomlinson et al. 2001) is folded and intruded by a Paleocene quartz monzonite. Paleomagnetic data indicate that this pluton postdate the folding (Somoza et al., in prep.).

The change from pyroxene-bearing basaltic to andesitic magmatism in the Upper Cretaceous to amphibole-rich magmas in the Lower Paleocene (Cornejo y Matthews, 2001), is attributed to an increase in crustal thickness associated with the "K-T" event, plus longer residence times in the lower crust, due to the inhibition of magma ascent by the compressional tectonic regime. The pulse of silicic magmatism which occurred from 60-57 Ma is attributed to upper crustal fusion, related to rising isotherms following the cessation of thickening. It is possible that crustal delamination also occurred, although no significant uplift, which should occur following such delamination, has been recognised in the Upper Paleocene.

The causes of the "K-T" compressional event are unknown but its intensity and short duration suggests an external cause such as, for example, a plate motion readjustment or the subduction of a buoyant structure such as an aseismic ridge.

CONCLUSIONS

The "K-T" compressive deformation interrupted a prolonged period of extensional basin formation during the late Upper Cretaceous. This event was of short duration (65-62 Ma) and inverted the Upper Cretaceous basins, forming a marked angular unconformity between the basin-fill sequences and the overlying Paleocene strata. Syntectonic magmatism was concentrated along the western margin of the inverted Cretaceous basins, and magma ascent was channelled along the reactivated basin-bounding faults. This magmatism comprised both intrusive and extrusive activity. A change in petrology from "drier" pyroxene-bearing magmas in the Upper Cretaceous, to hornblende-rich lithologies in the Lower Paleocene, is attributed to an increase in crustal thickness and longer deep residence times for the ascending magmas. Following the "K-T" event, extensional conditions were resumed from 60 Ma onwards, and large volumes of silicic magmas were generated by upper crustal fusion related to rising isotherms.

Table 1: Summary of Geochronological Data								
Sample	**Lithology**	**Location**	**UTM N**	**UTM E**	**Method**	**Mineral**	**Age ± Error (2 sigma)**	**Reference**
Upper Cretaceous sequences								
Llanta formation								
SAR-38b	Hornblende-pyroxene volcanic breccia	Sierra Caballo Muerto	7080620	423200	Ar/Ar	Hornblende	69,4 ± 0,6	
RIO-631	Hornblende-pyroxene volcanic breccia	Sierra Caballo Muerto	7079407	424147	Ar/Ar	Hornblende	72,0 ± 1,2	
RIO-742	Hornblende-pyroxene volcanic breccia	Sierra Miranda	7105748	438585	Ar/Ar	Hornblende	68,1 ± 1,1	
RIO-544a	Hornblende-pyroxene volcanic breccia	La Puerta	7000827	431958	Ar/Ar	Hornblende	65,7 ± 0,9	
RIO-444	Fluidal rhyolitic clast in sediments	Qbda. Chañaral Alto	7000258	433817	U/Pb	Zircon	ca. 69	**
RIO-449	Fluidal rhyolitic clast in sediments	Qbda. Chañaral Alto	7007636	431831	U/Pb	Zircon	65,2 ± 0.1	**
RIO-748	Welded rhyolitic ignimbrite	Sierra Miradora	7108320	441273	U/Pb	Zircon	76,8 ± 0,1	*
RIO-766	Welded rhyolitic ignimbrite	Pampa del Carrizo	7119141	447990	U/Pb	Zircon	76,7 ± 0,05	*
RIO-769	Bentonite layer with rhyolitic pumice fragments	Pampa del Carrizo	7123570	441797	U/Pb	Zircon	76,8 ± 0,1	*
Cerro Los Trigos Ignimbrites								
DCM-277	Biotite sanidine rhyolitic ignimbrite	E of Cerro Buenos Aires	7275491	418442	K-Ar	Biotite	76 ± 2	
JN-787	Potassic rhyolite	Pampa Mirador	7192000	417300	K-Ar	Biotite	75 ± 2	Naranjo and Puig (1984)
DCM-395	Biotite, pyroxene and hornblende rhyolitic ignimbrite	Salitrera Chile	7211202	416590	K-Ar	Biotite	75 ± 3	
DCM-184	Biotite sanidine rhyolitic ignimbrite	Cerro Islote	7227010	450221	Ar/Ar	Sanidine	72,9 ± 0,7	
DCC-143	Biotite sanidine rhyolitic ignimbrite	El Estanque	7193304	4574478	K-Ar	Biotite	71 ± 3	
Co. Los Carneros Strata								
SC-340	Dacitic tuff	Qda. San Andrés	7025100	449100	K-Ar	Hornblende	66 ± 4	
SC-336	Trachytic lava	Qda. Acerillo	7030500	449900	K-Ar	Whole rock	63 ± 2	
Lower Paleocene volcanic products								
Venado Formation								
RIO-694	Rhyolitic ignimbrite	S of Portezuelo Chimberos	7020006	408548	U/Pb	Zircon	63,7 ± 2,7	*
RIO-464	Hornblende pyroxene dacitic lava	Quebrada La Cortadera	7016544	435273	Ar/Ar	Hornblende	62,5 ± 0,9	
RIO-547		Quebrada La Cortadera	7016159	436080	Ar/Ar	Hornblende	62,5 ± 1,0	
RIO-381	Trachytic lava	Portezuelo Chimbero	7022055	407107	K-Ar	Whole rock	62,5 ± 1,5	

Table 1 (Contd.)								
Sample	**Lithology**	**Location**	**UTM N**	**UTM E**	**Method**	**Mineral**	**Age ± Error (2 sigma)**	**Reference**
Pampa del Carrizo Complex								
RIO-803	Hornblende biotite ignimbrite	Qbda. El Carrizo	7130106	434091	Ar/Ar	Hornblende	61,5 ± 1,8	
RIO-805a	Hornblende biotite rhyodacitic tuff	Qbda. El Carrizo	7131908	437395	Ar/Ar	Hornblende	62,2 ± 1,8	
RIO-680	Hornblende dacitic dome	N of Qda. Doña Ines Chica	7118121	428079	Ar/Ar	Hornblende	62,0 ± 0,6	
RIO-808	Biotite rhyolitic ignimbrite	Qbda. El Carrizo	7130731	431917	K-Ar	Biotite	63 ± 2	
RIO-806	Hornblende biotite dacite clast	Qbda. El Carrizo	7130787	437441	K-Ar	Biotite	65 ± 2	
Cerro Guanaco Complex (Altamira)								
RIO-820	Hornblende pyroxene and biotite dacitic dome	N of Cerro Guanaco	7152094	428579	K-Ar	Biotite	62 ± 2	
Morros Blancos complex (Altamira)								
RIO-874	Pyroxene hornblende biotite dacite	Morros Blancos	7180234	425284	K-Ar	Biotite	62 ± 2	
RIO-875a	Pyroxene hornblende biotite dacite	Morros Blancos	7180338	425564	K-Ar	Biotite	61 ± 2	
DCM-039	Pyroxene hornblende biotite dacite	Morros Blancos	7176316	424719	K-Ar	Biotite	63 ± 2	
DCM-036	Hornblende pyroxene biotite dacitic porphyry	Morros Blancos	7174625	424448	K-Ar	Biotite	63 ± 2	
DCM-042	Hornblende pyroxene biotite dacitic ignimbrite	N. De Cerro Morros Blancos	7171622	426132	K-Ar	Biotite	62 ± 2	
DCM-041	Pyroxene hornblende biotite dacite	N. De Cerro Morros Blancos	7171012	426209	K-Ar	Biotite	62 ± 2	
Catalina-Sierra del Toro Complex								
DCM-235	Horneblende biotite vitrophyre	N of Sierra del Toro	7233692	417125	K-Ar	Biotite	65 ± 2	
DCM-399	Horneblende biotite pyroxene vitrophyre	Salitrera Flor de Chile	7217954	419594	K-Ar	Hornblende	62 ± 2	
DCM-389	Horneblende biotite pyroxene vitrophyre	Salitrera Flor de Chile	7197431	421812	K-Ar	Biotite	63 ± 2	
Sierra Las Pailas Complex								
DCM-194	Pyroxene biotite hornblende dacyandesitic dome	Sierra Las Pailas	7219104	450367	K-Ar	Biotite	64 ± 2	
DCM-188	Hornblende pyroxene biotite dacyandesitic lava	S of Sierra del Argomedo	7231036	459015	Ar-Ar	Hornblende	64,0 ± 0,7	
<u>Syntectonic plutons</u>								
Cachiyuyo Pluton								
RIO-518	Pyroxene biotite monzodiorite	Cachiyuyo	7008220	406570	K-Ar	Biotite	62 ± 2	
RIO-519	Quartz-sericite-tourmaline rock	Cachiyuyo	7005095	404293	K-Ar	Sericite	61 ± 2	

Table 1 (Contd.)								
Sample	**Lithology**	**Location**	**UTM N**	**UTM E**	**Method**	**Mineral**	**Age ± Error (2 sigma)**	**Reference**
Copiapina Pluton								
RIO-375	Pyroxene biotite diorite	4 km SW of Cerro La Campana	7036264	410042	K-Ar	Biotite	63 ± 2	
RIO-523	Pyroxene biotite quartz diorite	4 km SW of Cerro La Campana	7036747	410167	K-Ar	Biotite	61 ± 2	
RIO-522	Muscovite quartz rock	4 km SW of Cerro La Campana	7036045	409734	Ar/Ar	Muscovite	62,2 to 64,7	
Upper Paleocene to Lower Eocene volcanic sequences								
Southern Segment (26º-27º S)								
El Salvador Caldera								
RIO-686	Sanidine rhyolitic ignimbrite	Los Amarillos	7099762	428567	Ar/Ar	Sanidine	57,8 ± 0,6	
RIO-688	Biotite rhyolitic ignimbrite	Los Amarillos	7101277	428405	Ar/Ar	Biotite	59,1 ± 0,6	
RIO-689	Biotite rhyolitic block in ignimbrite	Los Amarillos	7101327	428470	Ar/Ar	Biotite	59,2 ± 1,0	
RIO-729	Biotite rhyolitic ignimbrite	Los Amarillos	7103139	426496	Ar/Ar	Biotite	59,8 ± 0,4	
RIO-718	Sanidine biotite rhyolitic ignimbrite	W of Cerro Contreras	7090786	446375	Ar/Ar	Biotite	59,1 ± 0,4	
RIO-734	Hornblende pyroxene dacite porphyry	Los Amarillos	7099918	436004	Ar/Ar	Hornblende	57,8 ± 0,6	
La Banderita Caldera								
RIO-404	Fluidal rhyolitic ignimbrite	Sierra La Banderita	7027130	432503	U/Pb	Zircon	57,2 ± 0,5	*
SC-804	Pyroxene biotite dacite ignimbrite	E of Sierra La Peineta	7047855	428311	U/Pb	Zircon	56,6 ± 0,1	**
SC-808	Rhyolite ring dyke	E of Sierra La Peineta	7038866	429311	U/Pb	Zircon	55,4 ± 0,1	**
San Pedro de Cachiyuyo Caldera								
RIO-291	Sanidine biotite rhyolitic ignimbrite	S side of Sierra La Peineta	7039504	423185	K-Ar	Sanidine	53,5 ± 2,1	
Llano San Pedro Volcanotectonic depression								
RIO-262	Two pyroxene andesite lava	Llano San Pedro	7036249	425289	K-Ar	Whole rock	51,8 ± 1,3	
Central Segment (25º15'-26º S)								
Basal Ignimbrites								
RIO-826	Biotite rhyolitic ignimbrite	Between of quebradas Juncal y Carrizo	7140118	435988	K-Ar	Biotite	56,8 ± 1,4	
RIO-830	Biotite rhyolitic ignimbrite	Qbda. Del Carrizo	7132212	438124	K-Ar	Biotite	56,6 ± 1,9	
DCM-045	Pyroxene biotite vitrophyre	E of Cerro Chicoteado	7169014	437816	K-Ar	Biotite	56,2 ± 1,5	
DCM-072	Pyroxene biotite vitrophyre	E of Cerro la Pólvora	7153244	443825	K-Ar	Biotite	55,0 ± 1,4	
DCM-070	Pyroxene biotite vitrophyre	Cerro La Pólvora	7153737	439965	K-Ar	Biotite	54,3 ± 1,4	
DCC-145	Biotite rhyolitic ignimbrite	Qda. El Chaco S.	7187100	453275	K-Ar	Biotite	56,1 ± 1,7	

Table 1 (Contd.)								
Sample	**Lithology**	**Location**	**UTM N**	**UTM E**	**Method**	**Mineral**	**Age ± Error (2 sigma)**	**Reference**
Pampa Rubia Complex								
RSE-108	Pyroxene andesite lava	S of Pampa Rubia	7136530	443213	K-Ar	Whole rock	52,9 ± 1,8	
RSE-344	Piroxene trachyandesite lava	S of Pampa Rubia	7137241	439562	K-Ar	Whole rock	52,4 ± 1,2	
DCM-290	Pyroxene trachytic lava	S of Pampa Rubia	7133741	447081	K-Ar	Whole rock	57,5 + 1,9	
DCM-291	Pyroxene trachyandesite lava	S of Pampa Rubia	7134158	447286	K-Ar	Whole rock	57,3 + 1,9	
RIO-827	Biotite rhyolitic ignimbrite	Pampa Rubia	443122	7137974	Ar/Ar	Plagioclase	53,5 ± 0,7	
Pampa Lorca Complex								
RIO-846	Olivine basalt lava	NE of Altamira	7160654	430020	K-Ar	Whole rock	51,6 ± 0,9	
RSE-202	Two pyroxene andesite lava	Pampa San Juan	7174825	433291	K-Ar	Whole rock	50,9 ± 1,4	
DCM-049	Olivine pyroxene microdiorite	Cerro Chicoteado	7167651	432586	K-Ar	Whole rock	55,5 ± 2,9	
DCM-052	Olivine basalt lava	Cerro Chicoteado	7168284	430616	K-Ar	Whole rock	54,5 ± 1,8	
RSE-198	Pyroxene andesite lava	Sierra Aguilar	7173842	436009	K-Ar	Whole rock	50,5 ± 1,7	
RSE-206	Pyroxene olivine basaltic andesite	Cerro Chicoteado	7165630	433751	K-Ar	Whole rock	52,5 ± 1,8	
<u>Northern Segment (24-25º S)</u>								
Basal Ignimbrites								
DCC-137	Biotite rhyolitic ignimbrite	Pampa Copiapina	7193351	450739	K-Ar	Biotite	56,6 ± 1,4	
DCC-139	Biotite rhyolitic ignimbrite	Pampa Copiapina	7194304	450330	K-Ar	Biotite	57,4 ± 1,4	
DCM-081	Biotite rhyolitic ignimbrite	Cerro Campana	7224923	442866	K-Ar	Biotite	57,8 ± 1,5	
DCM-195	Biotite sanidine rhyolitic ignimbrite	Sierra Las Pailas	7217387	450891	K-Ar	Biotite	57,2 ± 1,7	
DCM-237	Biotite rhyolitic ignimbrite	SE of Cerro Buenos Aires	7250506	429421	K-Ar	Biotite	58,2 ± 1,5	
DCM-027	Biotite sanidine rhyolitic ignimbrite	Cerro Tres Tontos	7310628	452136	K-Ar	Biotite	59,2 ± 1,6	
Cachinal-Las Pailas domes								
DCM-226	Fluidal biotite rhyolite	W of Cerro Peñafiel	7241675	442230	K-Ar	Biotite	55,8 ± 1,5	
DCM-225	Fluidal biotite rhyolite	S of Cerro Peñafiel	7239415	442666	K-Ar	Biotite	56,1 ± 1,5	
DCM-200	Biotite sanidine rhyolite	Cerro Las Pailas	7210281	449036	K-Ar	Biotite	56,8 ± 1,4	
DCM-202	Biotite hornblende rhyolite dome	NW of Cerro Las Pailas	7212572	445115	K-Ar	Biotite	56,2 ± 1,5	
El Peñon domes								
H8-3	Biotite hornblende rhyodacite	Cerro Tostado	7297978	448173	K-Ar	Biotite	56,5 ± 1,5	
DR-4	Biotite dacite dome	Cerro Tostado	7297700	447600	K-Ar	Biotite	55,8 ± 1,5	
DCM-17	Fluidal biotite rhyolite	S of El Peñon Mine	7308052	450295	Ar/Ar	Biotite	54,5 ± 0,6	*
DCM-24	Silicified banded rhyolite dome	Quebrada Colorada	7304270	448375	U/Pb	Zircon	55,4 ± 0,2 54,4 ± 0,2	

K-Ar and Ar/Ar analyses were carried out in the Sernageomin Ar/Ar laboratory by Carlos Pérez de Arce, Stephen Matthews, Marcelo Yañez and César Vásquez. U/Pb analyses were carried out in the MIT Geochronology Laboratories by Mark Martin and Sam Bowring (*) and at the Geological Survey of Canada by Mike Villeneuve (**).

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