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Report on

1:100 000 Scale Geological and Metallogenic Maps

Sheet 3366-18

Provinces of San Luis and Córdoba

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GEOSCIENTIFIC MAPPING OF THE SIERRAS PAMPEANAS ARGENTINE-AUSTRALIAN COOPERATIVE PROJECT

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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SECTION I: GEOLOGY

By Peter G. Stuart-Smith

1. INTRODUCTION

1.1 LOCATION AND ACCESS

The *3366-18* 1:100 000 scale map sheet area straddles the southern part of the Sierras Comechingones within the San Luis and Córdoba Provinces; between latitude 32°40'-33°00' S and longitude 64°30'-65°00' W. The area lies within the **3366-II (Santa Rosa)** 1:250 000 scale map sheet.

The main population centres are the towns of Las Albahacas and Papagayos. Access is via Papagayos in the west and Las Albahacas in the east. The only access to the main range of the Sierras Comechingones is the unsealed track from Las Albahacas. Tributaries of the east-flowing Río San Bartolome comprise one of the main drainage catchments in this part of the Sierras.

1.2 NATURE OF WORK

The mapping of the Sierras Comechingones was carried out in 1995 and 1996 under the Geoscientific Mapping of the Sierras Pampeanas Argentina - Australia Cooperative Project by geologists from the Australian Geological Survey Organisation (AGSO) and the Subsecretaría de Minería, Argentina (Figs. 1, 2). The mapping employed a multidisciplinary approach using newly acquired high-resolution airborne magnetic and gamma-ray spectrometric data, Landsat TM imagery, and 1:20 000 scale (approximate) black and white air photography.

The **3366-18** geological map was compiled using topographic bases produced at photo-scale from rectified Landsat images controlled by field GPS sites. Topography, including cultural and hydrography data were derived from the rectified Landsat images, and the relief data was derived from the digital terrane model (DTM) acquired during the airborne geophysical survey.

Geologists involved in the fieldwork were P.G. Stuart-Smith (AGSO), and J.C. Candiani and H. Petrelli (DNSG).

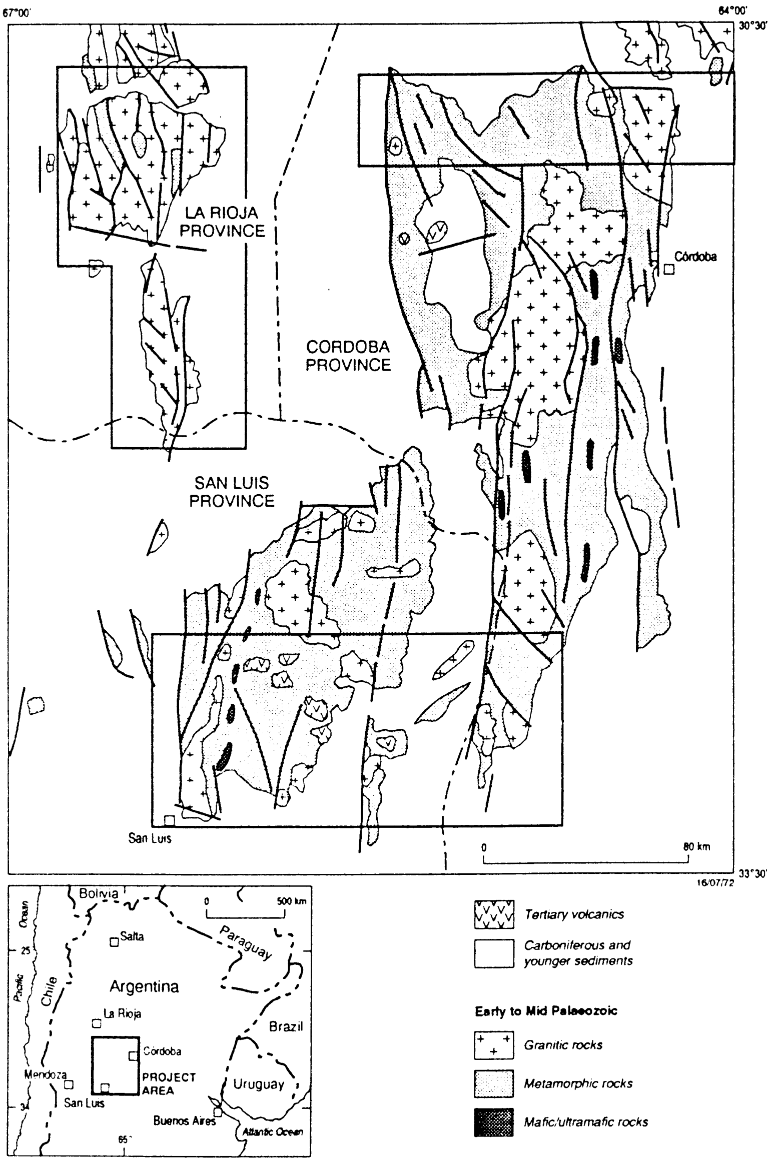

Figure 1. Simplified regional geology of the southern Sierras Pampeanas, and location of the three project areas of the Geoscientific Mapping Project, including the San Luis area.

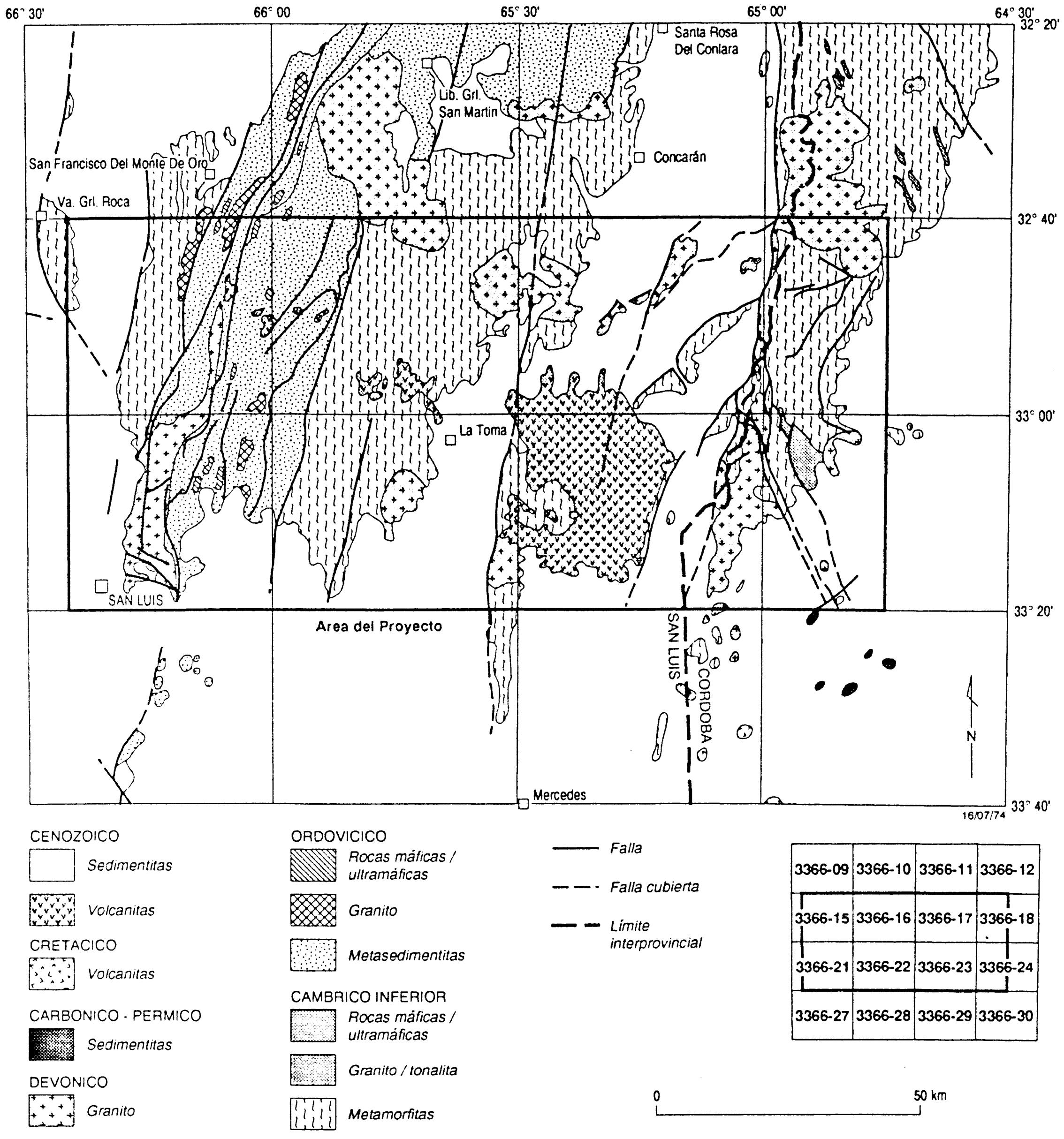

Figure 2. Location of the *Sierras de San Luis y Comechingones* 1:250,000 scale map area in San Luis and Córdoba Provinces with generalised geology. Locations of 1:100,000 scale map areas are indicated.

1.3 PREVIOUS INVESTIGATIONS

Previous geological investigations of the southern Sierras Comechingones includes regional 1:200 000 scale geological mapping of Hoja 24 by Sosic (1964) and stream sediment geochemical mapping of the Sierras Comechingones by Candiani and Maza (1982). More recent investigations have concentrated on aspects of the Cerro Aspero Batholith (Coniglio and Esparza, 1988; Pinotti and others, 1992; Esparza and Fagiano, 1995; and Pinotti and others, 1996).

2. STRATIGRAPHY

2.1 GENERAL RELATIONS

The Sierras Comechingones form the southeastern part of the Sierras Pampeanas, a distinct morphotectonic province of early- to mid-Palaeozoic metamorphic, felsic and mafic rocks that form a series of block-tilted, north-south oriented ranges separated by intermontane basins, in northwest Argentina. These ranges are bounded by escarpments developed on moderate to steeply dipping reverse faults developed during the Cainozoic Andean uplift (Jordan and Allmendinger, 1986).

Recent geological and geophysical surveys conducted during the Cooperative Argentine-Australia Project in the Sierras Pampeanas show that the Paleozoic basement of the southern Sierras Pampeanas contains of a number of distinct lithological, structural and metamorphic domains separated by major tectonic zones. There are two principal domains: an older, Cambrian domain, and a slightly younger, Ordovician domain. Both domains share a common geological history since early Devonian times. Only the older domain is present in the **3366-18** sheet area.

Rocks in the **3366-18** sheet area include the Monte Guazú and Conlara Complexes formed during the Early Cambrian Pampean Cycle. These units are intruded by an Early Devonian granites and are partly covered by Cainozoic continental deposits.

A summary of the stratigraphy and relations is shown in Table 1.

Table 1. Summary of stratigraphy and relationships in the sheet **3366-18**.

Age (Ma)	*Unit*	*Description*	*Relations*
CAINOZOIC QUATERNARY	Talus deposits.	Unconsolidated debris of metamorphic rocks derived from the Monte Guazú Complex	Deposits along steeply dipping contacts of the Comechingones and Alpa Corral Granites
	Alluvium	Unconsolidated clay, sand and gravel	Deposits along active river courses
	Fluvial fans	Unconsolidated bouldery gravels	Interfinger with alluvial deposits
TERTIARY TO QUATERNARY	Undivided loess and fluvial deposits	Clay, sand, gravel, paleosol	Mantles older units.
	Paleosols	Clay, soil, caliche	Forms thin cappings over basement rocks. Overlain by intercalated younger fluvial and aeolian deposits.
DEVONIAN (382 Ma)	Achiras Igneous Complex	Flow-banded granite and leucogranite, minor enclaves of banded gneiss, schist, amphibolite and pegmatite	Layered igneous complex. Intrudes Conlara Complex
	CERRO ASPERO BATHOLITH		
	Comechingones Granite	Pink coarse-grained porphyritic biotite granite, monzogranite and leucogranite	Intrudes Monte Guazú Complex, Uspara and Alpa Corral Granites
	Uspara Granite	Grey to pale pink, medium-grained, equigranular to weakly seriate leucogranite	Intrudes Monte Guaz Complex, Intruded by Comechingones Granite
	Alpa Corral Granite	Pink coarse-grained seriate, biotite monzogranite	Intrudes Monte Guazú Complex, Intruded by Comechingones Granite
CAMBRIAN	Conlara Complex	Pelitic and psammitic schist, amphibolite, granite, pegmatite	Faulted against Monte Guazú Complex. Intruded by Achiras Igneous Complex
	Monte Guazú Complex	Banded garnet-sillimanite-muscovite-feldspar-quartz gneiss, tonalitic ortho-gneiss, marble, calc-silicate rocks, meta-mafic rocks	Intruded by Cerro Aspero batholith, faulted against Conlara Complex

2.2 PALAEOZOIC METAMORPHIC BASEMENT

2.2.1 CAMBRIAN

Monte Guazú Complex (€ggn, €ga, €gt)

Pelitic gneiss, tonalitic orthogneiss, meta-mafic rocks, marble and calc-silicate rock

The Monte Guazú Complex is the main basement unit forming the southern Sierra de Comechingones. The area was mapped by Candiani and Maza (1982) as part of stream-sediment geochemical mapping program, and later, in the south, Otamendi and others (1996) mapped and described the unit as "Metamorfitas Monte Guazú", including it in the Las Lajas Complex. The unit extends from south from Cerro El Mogote, occupying the full width of the Sierra de Comechingones. Outcrop of the Complex is good to excellent in the sierras with gneiss forming low strike ridges. Meta-mafic rocks crop out as small isolated hills and also form the bulk of the magnetic anomalies within the unit.

The complex comprises interlayered metasedimentary and meta-intermediate and mafic rock, all of which were metamorphosed and deformed during the Early Cambrian Pampean Cycle. In the north, the unit is intruded by the Alpa Corral, Comechingones and Uspara Granites of the Cerro Aspero Batholith. In the southwest, the unit is faulted against and thrust over the Conlara Complex. A thin veneer of unconsolidated Cainozoic continental sediments limits the easterly extent of the complex with erosional remnants forming cappings along the higher parts of the Sierra de Comechingones south of Cerro Mogote.

The complex contains four main lithologies: pelitic gneiss; tonalitic orthogneiss; meta-mafic rocks; and minor marble and calc-silicate rocks. All are interlayered, and have the same medium-grade metamorphic and deformational history. Both the tonalitic orthogneiss and the meta-mafic rocks are interpreted as originally intrusive into the metasedimentary protoliths. Although having a similar composition and deformational/metamorphic history as the Conlara Complex, the latter complex is distinguished by the absence of tonalitic orthogneiss and the less feldspathic nature of the pelitic gneiss.

Banded, grey, garnet±sillimanite±muscovite-K-feldspar-biotite-plagioclase-quartz gneiss is the most abundant rock type, comprising about 80% of the Monte Guazú Complex. It is interlayered with minor calc-silicate rock, tonalitic orthogneiss and contains boudinaged pods of amphibolite, marble and pegmatite. Leucosome lenses and bands, a few cm's wide, are common and, in places, the texture is migmatitic. The medium-grade gneissic fabric is mostly rotated into parallelism with moderately-ENE dipping penetrative D3 shear planes. In zones of higher D3-strain, such as near Las Albahacas, this foliation has almost obliterated earlier fabrics and the gneiss is converted to mylonite with biotite replaced by chlorite and hematite, and sillimanite altered to fine muscovite aggregates.

Grey equigranular tonalitic orthogneiss is the second most abundant lithology within the Monte Guazú Complex. It is interlayered with the other rocks and is faulted against the structurally underlying Conlara Metamorphic Complex. The rock consists essentially of granoblastic polygonal medium-grained plagioclase and quartz, with biotite ± hornblende. Accessories include zircon, apatite, allanite, magnetite and rare pyrite. Rare muscovite occurs as porphyroblasts and as microcrystalline secondary folia. The principal penetrative foliation (S1), is defined by aligned biotite, and a weak mineral lineation (L1) is defined by aligned biotite and quartz ribbons. Weak chlorite, hematite, carbonate, sericite and epidote alteration is widespread, especially within D3 mylonitic zones, such as near Las Albahacas. Geochemically the gneisses are oxidised and metaluminous to slightly peraluminous with ASI ratios of between 0.9 and 1.1, falling within the I-type field of Chappell and White (1974).

Meta-mafic rocks, are interlayered throughout the complex forming isolated pods or semi-continuous bands that are boundinaged within the penetrative, D1 metamorphic fabric. Individual bodies range from a few metres to more than one kilometre in length. Pegmatite commonly forms small fringes developed at boudin necking points. The rocks are mostly banded ortho-amphibolite comprising weakly aligned fine- to medium-grained subprismatic hornblende, with granoblastic polygonal plagioclase and quartz, and minor titanite. Minor diopside, carbonate, muscovite, K-feldspar and epidote may also be present. Minor meta-gabbro, comprising subprismatic anthophyllite, granoblastic polygonal plagioclase, biotite, minor micrographic K-feldspar-quartz, magnetite and zircon, occurs within tonalitic gneiss (A95PS111). The rocks preserve a differentiated medium-grade gneissic fabric formed during D1 which was little affected by later deformation. Similar meta-mafic rocks to those in the Monte Guazú Complex occur north of the Cerro Aspero Batholith. These have been interpreted as transitional tholeiites with within-plate affinities (Demichelis and others, 1996), which were derived from a primary basic magma generated by low-degree partial-melting of an OIB-type asthenospheric mantle source (Demichelis and others, 1996).

Marble and banded calc-silicate gneiss, are a minor consituents of the complex, forming isolated bodies, particularly in the west near Cerro Morro.

Several generations of pegmatite dykes intrude basement metamorphics and granitic rocks. The oldest are represented by zoned garnet-muscovite-rich types that form small deformed pods, up to several metres wide within the gneiss of the Monte Guazú Complex. These pegmatites are probably the product of partial melting during M1 (Cambrian) metamorphism.

Conlara Complex (€cgn, €ce)

Pelitic and psammitic schist and gneiss; orthogneiss, minor calc-silicate rock and marble; pegmatite.

The Conlara Complex, comprises the majority of the basement outcropping within the valley (Valle del Río de Conlara) between the Sierras de San Luis and Sierra de Comechingones. Only the eastern part of the complex is exposed in the 3366-18 sheet area where it is faulted against the Monte Guazú Complex in the southwest. The Conlara Complex incorporates the metamorphic part (the "Metamorfítas y Anatexítas India Muerta") of a previously defined metamorphic-intrusive complex, the Achiras Complex (Otamendi and others, 1996), in the extreme south of the Sierra de Comechingones. The igneous part of the Achiras Complex of Otamendi and others (1996) has been redefined as the Achiras Igneous Complex.

The Conlara Complex comprises dominantly late Neoproterozoic - early Cambrian sediments, and was polymetamorphosed in the early-mid Palaeozoic. The thickness of the originanal sedimentary sequence is unknown due to the complex structures, including transposition foliation, and the lack of definitive bedding. The Complex is intruded by a series of subconcordant granite sheets of the Devonian Achiras Igneous Complex, which post-date the dominant structural and metamorphic episodes.

Metapelitic and metapsammitic quartz-feldspar-biotite-muscovite-garnet-sillimanite ±tourmaline±chlorite schist is the most abundant rock type in the Conlara Complex (approximately 50%). The schist contains a well-developed biotite-muscovite foliation that in the area dips shallowly to the east. Strongly corroded sillimanite, biotite coronas on garnet, and coarse poikiloblasts of muscovite and quartz containing tightly crenulated inclusions of sillimanite, suggest that the dominant fabric is a low temperature overprint of an earlier higher-grade (amphibolite-facies) fabric. Biotite and muscovite define a generally east-plunging mineral lineation while shear-sense indicators are well developed and show a dominantly east-up displacement. In places, the schist contains a metamorphic differentiated layering that consists of alternating leucosome and millimetre-scale quartz-rich layers.

Metapelitic and metapsammitic quartz-feldspar-biotite±garnet±sillimanite gneiss is the next most abundant unit within the Conlara Complex (~40%). It is clearly distinguished from the schist by the paucity of muscovite in the foliation, and more massive outcrop style. Where secondary muscovite is developed, it is generally unoriented and a minor component of the mineral assemblage, or it is associated with discrete overprinting shear bands, where it is associated with biotite. Leucocratic and/or pegmatitic veins are common in this rock type and typically define the main foliation, which is tightly to isoclinally folded (and refolded) at a meso- to microscopic scale.

Felsic orthogneiss is interlayered with both the gneiss and schist and constitutes a relatively minor component of the complex. The orthogneiss is strongly foliated and consists dominantly of equigranular quartz, feldspar and biotite with minor muscovite. The foliation in the orthogneiss appears to be contiguous with the earliest fabric in the enclosing rocks and suggests that the original granite was emplaced during the early Cambrian Pampean Orogeny.

Calc-silicate and marble, found within the unit to west in the Sierra de Yulto, Sierra Los Morillos, Sierra del Morro and Sierra de La Estanzuela, are not present in the sheet area.

Various generations of quartz-feldspar-biotite±muscovite±tourmaline±garnet pegmatite also occur within the Conlara Complex. Early generations are strongly deformed and are elongate and boudinaged in the schist and gneiss. Later generations are somewhat less deformed and are spatially associated with Devonian granites. The magnetic susceptibility of the pegmatites is extremely low. Late-stage quartz-tourmaline dykes and veins that are generally stongly lineated, are also common within the complex and are typically found in NW or SW trending sets.

2.3 PALAEOZOIC IGNEOUS ROCKS

In the Sierras Comechingones Palaeozoic igneous rocks were intruded into the Monte Guazú Complex, and to a less extent within the Conlara Complex, during the Cambrian (Pampean Cycle). These intrusions were deformed and metamorphosed to metagabbro, amphibolite and granitic/tonalitic orthogneisses. These rocks are described as part of the Metamorphic Basement, above. The most significant phase of magmatism occurred later during the Devonian Achalian Cycle when the granitic bodies of the Cerro Aspero Batholith and the Achiras Igneous Complex were emplaced. The presence of multiple phases of pegmatite crosscutting Devonian structures in the Devonian granites suggests that the magmatic phase was fairly extended in time and was penecontemporaneous with the deformation cycle.

2.3.1 DEVONIAN INTRUSIVES

Alpa Corral Granite (Cerro Aspero Batholith) (Dgae, Dgas)

Pink coarse-grained, equigranular to seriate, biotite monzogranite

The Alpa Corral Granite is a circular concentrically zoned pluton about 8 km across and covers an area of about 50 km^2, forming the southeastern part of the Cerro Aspero Batholith, in the Sierra Comechingones in the northeast of the area. Detailed geological mapping and petrographic studies of the pluton have been carried out by Coniglio and Esparza (1988), Pinotti and others (1992 and 1996) and Esparza and Fagiano (1995). The area was also mapped by Candiani and Maza (1982) as part of an exploration program in the Sierra Comechingones.

Exposure of the granite is good, particularly of the border facies which forms a prominent discontinuos ridge circling much of the pluton. The main central porphyritic phase is less well exposed, cropping out as low pavements and boulders, separated by active alluvial plains which drain mostly into the Río San Bartolome.

The granite is an earlier phase of the Cerro Aspero Batholith and is intruded by the Comechingones Granite to the north and by numerous late-stage aplite and fluorite-bearing pegmatite dykes. The pluton intrudes interlayered gneiss and amphibolite of the Monte Guazú Complex with marked discordance in most places, interdigitating locally. Within 500 m of the granite, along the eastern margin a penetrative greenschist facies mylonitic foliation in the metamorphic rocks, normally dipping shallowly to east (30°), steepens progressively towards the contact where it is subvertical, indicating at least some forceful diapiric emplacement of the pluton. Contact metamorphic effects are typically extensive recrystallisation with the development of cordierite at the expense of biotite in gneisses, epidotisation of amphibolite and areas of greisenisation and silicification (Pinotti and others, 1996).

The pluton comprises two main phases: a central seriate phase and an outer equigranular border facies. The main phase is a pink coarse-grained seriate, biotite monzogranite, with minor perthitic microcline phenocrysts up to 5 cm across and numerous biotite-rich schlieren (Coniglio and Esparza, 1988) and microgranular mafic enclaves up to 30 cm (Coniglio and Esparza, 1988; Pinotti and others, 1996). Accessory minerals include zircon, fluorite, apatite, xenotime, monazite, titanite, ilmenite, rutile, beryl, molybdenite and anatase (Pinotti and others, 1992, 1996). The granite is weakly sericitised and chloritised. The main phase grades locally into a strongly porphyritic phase and into a border phase of the same composition which is equigranular in texture. This latter phase crops out mainly along the southern and northeast borders and in the centre of the pluton where it forms a shallow dipping cap overlying the main phase (Pinotti and others, 1992).

The granite is well-jointed and veined by quartz in places. Minor steeply dipping SE-trending cataclasite zones, up to 2 m wide, with chalcedony, hematite and fluorite cut the pluton and the outer phase of the adjacent Comechingones Granite. Neodymium and strontium isotope studies indicate an age of 117±26 Ma for a fluorite occurrence in the Alpa Corral Granite and an unconformity-related origin associated with mixed ascending and “descending” hydrothermal fluids of low-to moderate temperatures (Galindo and others, 1996).

Whole rock geochemistry of the pluton confirms that both the Alpa Corral granite and Comechingones Granite together form a fractionated suite. The granites fall within the Anomalous granite field and are slightly peraluminous with ASI indexes of around or above 1.1. The granites are oxidised, however, magnetite is not common in the Alpa Corral Granite with mean magnetic susceptibilities less than 100 x 10^{-5} SI.

Previous authors have placed the granite in the G2 group of Rapela and others (1990) and infered an Ordovician age (eg. Pinotti and others, 1992, 1996). However, the granite truncates Early Devonian greenschist shear zone fabrics within the Monte Guazú Complex indicating a maximum age for the unit.

Uspara Granite (Cerro Aspero Batolith) (Dgu)

Medium-grained, equigranular to weakly seriate leucogranite

Previously unmapped granite crops out semi-continuously along the base of the Comechingones range for about 12 km south of Papagayos. The granite also forms low exposures along route 1 in the San Luis Province in the vicinity of A° Uspara, after which the granite is named. The granite is non-magnetic (magnetic susceptibility $<10 \times 10^{-5}$ SI), and aeromagnetic anomalies indicate that it is considerably more extensive in the shallow subsurface over much of the plain to the west of Papagayos.

The pluton is a grey to pale pink, medium-grained, equigranular to weakly seriate leucogranite. Primary muscovite and biotite are equally abundant and comprise together about 5% of the rock. Anhedral quartz forms scattered phenocrysts up to 1 cm across. Patches and veins of muscovite-tourmaline-feldspar quartz pegmatite are common. There is no chemical or isotopic data available.

The relationship with adjacent units is not known. Along the base of the Comechingones the granite is highly altered (kaolinised and chloritised), brecciated and cut by numerous moderately east-dipping faults. Kaolinite has been extracted from several quarries located in the area. These faults form part of the 1-2 km wide Cainozoic reverse fault zone along which the present ranges have been uplifted. Towards the top of the fault scarp, the granite contact with the overlying Monte Guazú Complex dips shallowly to the east and is inferred to be intrusive. At Papagayos the Comechingones Granite truncates the northern extent of the Uspara Granite. The contact, not exposed between the two plutons, is interpreted to be either faulted or intrusive. The lack of any high grade deformation fabrics (primary biotite is undeformed and shows only very weak hematite alteration) and the spatial relationship of the granite to the Cerro Aspero Batholith, suggests it may be part of the Devonian batholithic suite, possibly an earlier peraluminous phase which is intruded by the later Comechingones Granite.

Comechingones Granite (Cerro Aspero Batolith) (Dgol, Dgog, Dgoa)

Pink coarse-grained porphyritic biotite granite, monzogranite and leucogranite

The Gomechingones Granite, referred to as the El Talita pluton by Pinotti and others (1996), is the main pluton of the Cerro Aspero Batholith, forming the central part of the Sierra de Comechingones. Detailed studies of aspects of the granite has been made by Coniglio and Esparza (1988), and Pinotti and others (1992 and 1996). Only the southern part of the pluton is exposed in the extreme north of the sheet area where it extends the full width of the Sierras. The granite is well-exposed in rugged rocky mountains, deeply dissected by watercourses which follow the main fracture pattern in the granite.

An unbroken, curvlinear southern contact margin suggests that the pluton is probably the youngest in the Cerro Aspero Batholith, intruding, both the Alpa Corral Granite and probably the Uspara Granite. Both contacts are either not exposed or are difficult to locate in the field. However, they can be readily defined by coincident boundaries on aeromagnetic, spectrometric and Landsat TM imagery. The pluton intrudes the Monte Guazú Complex with a medium-to high grade contact metamorphic aureole extending up to 500 m from the granite. Within the aureole the rocks are intensely recrystallised with the development of cordierite at the expense of biotite and areas of greisenisation, silicification and epidotisation (Pinotti and others, 1996). The contact is well exposed east of Papagayos, where an intricate intrusive contact with tonalitic gneiss is preserved and, in places, is strongly sheared parallel to the subvertical ESE-trending intrusive contact. Intrusion appears to be syntectonic with respect to the shearing as pegmatite, aplite and granite veins both crosscut and form boudinaged stringers within the zone. The pluton is intruded by numerous aplite and pegmatite dykes, interpreted as late-stage fractionated phases which intruded along structurally controlled concentric and radial fractures within the cooling pluton. Minor steeply dipping SE-trending and fluorite-bearing cataclasite zones are also present in the outer phase, but are more common in the adjacent Alpa Corral Granite.

In the sheet area, the pluton comprises two main granitic phases, the outer comprising a border facies 6 to 8 km wide. The zones probably represent separate pulses of fractionated magma during batholith emplacement. The contact between the two phases is well-defined on Landsat TM and aeromagnetic imagery and is possibly gradational.

The inner phase consists of pink coarse-grained porphyritic biotite granite to monzogranite with up to 5% biotite. Accessory phases include titanite, apatite, zircon and allanite. K-feldspar megacrysts up to 5 cm across are also present and are weakly aligned parallel to the contact with the outer phase. Pinotti and others (1992) suggested that that orientation of the megacrysts was a product of simple shear generated during emplacement. Xenoliths of biotite microgranite are rare. The outer phase is more felsic and less altered and comprises pink, coarse-grained, porphyritic biotite-leucogranite with K-feldpar phenocrysts up to 3 cm across. Most biotite is chloritised, and sericitic and hematitic alteration is common.

Whole rock geochemistry of the pluton confirms that both phases and the phases of the Alpa Corral granite together form a fractionated suite. The granites fall within the Anomalous granite field and are slightly peraluminous with ASI indexes of around or above 1.1 . The granites are oxidised with magnetite a common accessory phase and mean magnetic susceptibilities above 800 x 10^{-5} SI for the inner phase and 200-300 x 10^{-5} SI for the outer phase.

Previous authors have have placed the granite in the G2 group of Rapela and others (1990) and infered an Ordovician age (eg. Pinotti and others, 1992, 1996). However, the granite truncates Early Devonian greenschist shear zone fabrics within the Monte Guazú Complex indicating a maximum age for the unit. Not isotopic age determinations are available for the unit. Similar, intrusive relations and whole rock and trace element chemistry are consistent with the batholith being part of the Early Devonian Achalian Cycle, rather than the older Ordovician Famatinian Cycle.

Achiras Igneous Complex

Interlayered granite, leucogranite

An intrusive complex, defined as the Achiras Igneous Complex, forms the extreme south of the Sierras Commechingones centred on the town of Achiras and is present in the southwest corner of the sheet area where it intrudes the Conlara Complex. This complex comprises the intrusive part (the “Granito Los Nogales”) of what was previously termed the Achiras Complex by Otamendi and others (1996). Outcrop of the the complex is good.

The intrusive complex comprises a stratified, subconcordant granite suite. The unit consists mainly of two different granite types, a coarse-grained seriate strongly magnetic granite and a non-magnetic equigranular leucogranite-granite. Only the latter phase is present in the sheet area where it forms sheet-like bodies, displaying mostly concordant but intrusive contacts, postdating earlier, differentiated, high-grade metamorphic fabrics within the Conlara Complex rocks. U-Pb zircon age determinations of the magnetic granite phase yield a crystallisation age of 382 ± 6 Ma (Camacho and Ireland, 1997). This contrasts the age interpreted by previous authors (eg. Fagiano and others, 1992; Nullo and others, 1992) who inferred an Early Ordovician age for the granite, correlating it with the syn D2 granitic group of Rapela and others (1990).

The granite is typically a pink to grey, medium- to coarse-grained, equigranular biotite-granite to leucogranite with a ubiquitous flow-banded fabric evident by aligned biotite, concordant pegmatitic bands and patches, and schlieren and lenses of pelitic gneiss. Zircon, apatite, and rare garnet are accessory phases. Muscovite is a minor primary consituent but is more abundant as a secondary mineral in zones adjacent to the Las Lajas Shear Zone south of the sheet area where the granite has a mylonitic fabric. Very weak carbonate, epidote, sericitic and hematitic alteration is widespread.

Minor interlayered grey banded, feldspar-biotite-quartz (±garnet±muscovite) gneiss and (±garnet±sillimanite±feldspar) muscovite-biotite-quartz schist occur throughout the igneous complex as concordant enclaves and xenoliths derived from the enclosing Conlara Complex.

Geochemically both the equigranular granite-leucogranite and the seriate granite (present south of the sheet area) form a fractionated suite, the former the most fractionated. They have similar major and trace element trends to other Devonian granites, and are peraluminous with an ASI of about 1.1. However, they differ in that they show little enrichment in Rb, Y, U with fractionation compared to other granites of the same age and are mostly less oxidised.

The granites have been interpreted as products of local anatexisis (Fagiano and others, 1992; Nullo and others, 1992; Otamendi and others, 1996) with emplacement conditions estimated at 700°C and 3Kb (Fagiano and others, 1992). This interpretation has been largely based on the interpretation of a tectonic origin for biotite alignment in the granites and a correlation with the principal second deformation phase (D2) of Dalla Salda (1984).

It is clear from this study that the alignment of biotite is a product of magma flow and that the granite truncates both D1 and D2 fabrics and is only affected by greenschist facies deformation. The granites probably represent products of a fractionated granitic magma, derived from metasedimentary sources, which intruded the Early Cambrian metamorphic rocks at mid/upper crustal levels during the Early Devonian as a series of multiple injections during progressive mylonitisation and eventual truncation by a greenschist facies high-strain zone, differentiated as the Las Lajas Shear Zone in the 3366-24 sheet area to the south.

A major swarm of pegmatites is spatially associated with the Achiras Igneous Complex. The pegmatites occur as either semi-concordant veins intruding both granitic and gneissic rocks, or as discordant, mostly NW- and NNW-trending tourmaline-bearing veins. The concordant variety form part of the layered granite complex and represent highly fractionated melts injected during multiple granite intrusion. In the area, the discordant variety are more common and more widely distributed than the earlier pegmatites. Regionally they are spatially associated with the Las Lajas Shear Zone to the south, and are concentrated within the adjacent Conlara Complex where they crosscut folds formed during the mylonite formation, and in places, are themselves strongly mylonitised. These relationships indicate that the discordant pegmatites intruded during thrusting on the Las Lajas Shear Zone and represent the final products of felsic magmatism in this region.

2.3.3 MINOR DYKE ROCKS

Pegmatite (peg)

Numerous pegmatite dykes intrude the basement of the Sierras Comechingones. There are two main generations in the sheet area:

1. Pegmatites emplaced within the Conlara and Monte Guazú Complexes during M1 metamorphic peak in the Cambrian, at around 530-515 Ma.

2. Pegmatites emplaced during the Devonian, and associated with the Cerro Aspero Batholith and the Achiras Igneous Complex.

Aplite

In the northeast, a swarm of aplite dykes, up to 200 m wide and 5 km long, intrudes the Cerro Aspero batholith and the Monte Guazú Complex. The dykes, concentrated near the contact of the Comechingones and Alpa Corral Granites, intrude along a well-developed ring fracture system, paralleling the contact of the Comechingones Granite. The dykes comprise pink fine- to medium-grained equigranular biotite-muscovite-bearing aplite, commonly with minor quartz veinlets. Chloritic, hematitic and sericitic alteration is also common. A high total count (180 cps) reflects high potassic and thorium contents. The dykes are probably late fractionates associated with the Comechingones Granite.

Lamprophyre

A swarm of long linear lamprophyre (minette) dykes intrudes the Monte Guazú Complex in the south. Individual dykes, are up to 10 m wide, and extend discontinuously for up to 10 km. Typically, the dykes are negative topographic features and poorly exposed as small, spheroidally-weathered boulders, lying between resistant outcrops of the basement rocks. A chilled margin is commonly developed in the lamprophyres. The dykes trend northwesterly, parallel to faults developed at the close of the Devonian Achalian deformation.

The precise age of the dykes is not known, however, they clearly postdate Late Devonian thrusts and therefore must be late Paleozoic or Mesozoic in age. Toselli and others (1996) interpret similar lamprophyre dykes, intruding the Granito Ñuñorco in the western Sierras Pampeanas, to be related to the late Devonian/upper Carboniferous "Chánica Orogeny".

2.4 CAINOZOIC

Tertiary to Quaternary

Paleosols (**Czc**)

In the higher parts of the Sierras Comechingones and at the eastern foot of the ranges, paleosols (**Czc**), commonly with a hardpan of calcrete, form thin (a few metres thick) remnant cappings over basement rocks. They are best exposed along the gently sloping eastern flanks of the ranges where they are overlain by intercalated Tertiary to Quaternary fluvial and aeolian deposits. The age of the deposits is not known. Their formation predates the last significant uplift which probably took place during the Late Pliocene-Pleistocene (Costa, 1996).

Undivided loess, alluvial deposits, fans, gravels, caliche, channel deposits (Czu)

The most extensive Cainozoic unit (**Czu**) is an intercalted sequence of undifferentiated Tertiary to Quaternary fluvial and aeolian deposits and paleosols which cover a large part of the Pampean region and onlap the base of the Sierras Comechingones in the east. The unit consists of pinkish loess intercalated with fluvial and aeolian deposits comprising mostly friable illite and silt, with material derived from both the metamorphic-igneous basement rocks and a volcanic-pyroclastic source (Strasser and others, 1996). Strasser and others (1996) have correlated the stratigraphically younger deposits in the San Luis region with Late Pleistocene and Holocene units in the Buenos Aires Province.

2.5 QUATERNARY

Active alluvial deposits (Qa, Qg)

Holocene (Santa Cruz, 1978) to Recent fluvial fan deposits of unconsolidated bouldery gravels (**Qg**) interfinger downslope with finer-grained **Qa** alluvial deposits along the base of the western fault scarp bordering the Sierra Comechingones. The latter include deposits of clay, sand and gravel along active river courses and adjacent terraces. The most extensive deposits are developed on the loess plain east of the Sierra Comechingones.

Active talus deposits (Qt)

Minor Recent talus deposits of gneissic debris, derived from the Monte Guazú Complex, occur along the exhumed steeply dipping contacts of the Comechingones and Alpa Corral Granites in the north.

3. TECTONICS

Three major deformation/metamorphic and magmatic events have affected the basement rocks of Sierras Comechingones (the Monte Guazú, and Conlara Metamorphic Complexes). The three tectonic events are the Early Cambrian Pampean Cycle, the early Ordovician Famatinian Cycle, and the Devonian Achalian Cycle. The region was also affected by reverse faulting and block-tilting during the Cainozoic Andean Cycle.

3.1 PAMPEAN CYCLE

Early Cambrian deformation and metamorphism

The oldest preserved structural feature in Sierras Comechingones is a medium- to high-grade metamorphic differentiated foliation which is well-preserved in pelitic gneiss and amphibolite of the Monte Guazú and Conlara Complexes. The foliation (S1), which is variably developed, is typically a penetrative gneissic foliation in pelitic gneiss, defined by leucosome lenses and a mineralogical layering defined by biotite, quartz and sillimanite with a lineation (L1) defined by sillimanite and quartz. In tonalitic orthogneiss, aligned biotite forms S1 folia, with a weak biotite and quartz lineation. In amphibolite and calc-silicate rocks the foliation forms strongly differentiated mineralogical bands with aligned hornblende. Throughout both metamorphic complexes the S1 foliation, trends NNW and dips ~45° to the east.

Sillimanite-garnet assemblages in pelitic gneiss indicate M1 metamorphism was at least amphibolite facies and abundant muscovite-pegmatites, and leucosome (forming subconcordant lenses with S1) suggest limited partial melting took place. Pressure-temperature (*P–T*) estimates of peak metamorphic conditions for rocks equivalent to the Monte Guazú Metamorphic Complex in the Sierra Comechingones range from 6.1 to 9.5 Kb, at 700 to 800 °C (Gordillo, 1984; Martino and others, 1994; Cerredo, 1996).

No isotopic data exist from Sierras Comechingones to constrain the age of the Pampean Cycle. However, uranium-lead dating of zircon and monazite from Córdoba, farther to the north, which grew during M1 in *Sierras de Septentrionales* (Lyons and others, 1997), give an age of ~530Ma (Camacho and Ireland, 1997). Late Pampean granites in Córdoba give an age of ~515-520 Ma (Camacho and Ireland, 1997; Rapela and Pankhurst , 1996; AGSO-Subsectretaría de Minería Argentina, unpublished data).

3.2 FAMATINIAN CYCLE

Ordovician deformation and metamorphism

In the early Ordovician a widespread deformation, metamorphic and magmatic event (the Famatinian Cycle) affected the southern Sierras Pampeanas. Numerous intrusives within the La Rioja area were emplaced around 490-480 Ma (Camacho and Ireland, 1997) and probably represent the core of the associated magmatic arc which developed at that time within a late Cambrian subduction/accretionarty Complex.

In gneiss and schist of the Conlara Complex, in particular, those structurally beneath the Las Lajas Shear Zone south of the **3366-18** sheet area, a schistosity parallel to S1 developed,forming the main penetrative structure. Earlier formed S1 fabrics were rotated into parallelism, forming a new S2 foliation with a pronounced mineral lineation (L2) of biotite, muscovite and quartz. Lower amphibolite/upper greenschist facies metamorphism (M2) is indicated. Quartz-feldspar leucosome, formed during M1, are deformed into asymmetrical clasts indicating westward-directed thrusting. In places, the schistosity is axial plane to relict isoclinal folds (F2) which plunge parallel to the lineation. These folds are also present in Monte Guazú Complex gneiss, however, S2 development was limited.

3.3 ACHALIAN CYCLE

Devonian deformation and metamorphism

The Achalian deformation and magmatic cycle affected the southern Sierras Pampeanas where it was associated with widespread thrusting, retrogression and grantitic intrusion Characteristically, the deformation induced by east-west compression, involved repeated partitioning of strain between zones of strike-slip displacement and zones of thrusting, with repeated overprinting relationships. Domains between shearing were folded and refolded. In the area, two distinct styles of deformation are recognised:

1. thrusting at low-grade in discrete shear zones with penecontemporaeous folding and crenulation of the earlier formed mylonitic fabrics, and

2.brittle-ductile strike-slip faulting typically in conjugate sets trending generally NW and SW.

Thrusts and mylonitic zones

Locally, throughout the sheet area, medium-grade D1 and D2 fabric elements are rotated into parallelism by a shallowly- to moderately-dipping, penetrative D3 shear fabric associated with westerly-directed thrusting. This episode is marked by the development of mylonite in high-strain zones and pervasive, retrogressive greenschist-facies metamorphism. To varying degrees, this deformation affects all basement rocks in the region, including a number of the Early Devonian granites. Within the area, zones of high-strain were focussed in a major mylonite zone along the eastern flank of the Sierra de Comechingones, passing through Las Albahacas.

Within mylonite zones, pelitic gneiss of the Monte Guazú Complex is converted to schist or mylonite with a penetrative S3 spaced shear plane or mylonitic foliation of chlorite and sericite. Quartz is recrystallised to ribbons, biotite is deformed and replaced by chlorite, hematite and geothite, and M1 sillimanite is altered to fine muscovite aggregates. A mineral lineation (L3) or slickenline plunges down-dip to the ENE and is defined by aligned muscovite, chlorite, quartz and rotated relict biotite. Sheath folds are also present, in places, plunging parallel to L3. Kinematic indicators including, asymmetric mantled K-feldspar-quartz clasts and garnet augen, S-C-C' fabrics: all indicate westward-directed trusting parallel to L3.

Although the D3 mylonitic fabric is most intense in the less competent pelitic gneiss, other rocks also form mylonite. In ortho-amphibolite (Monte Guazú Complex), bands of recrystallised quartz, carbonate, plagioclase and epidote define a penetrative greenschist facies mylonitic foliation, and in pegmatite, S3 is present as recrystallised granoblastic polygonal bands of quartz and deformed muscovite folia.

Between high strain zones, S3 is present as either a spaced shear plane, or a crenulation which is axial plane to ENE-plunging tight to isoclinal folds (F3). The parallelism of these folds to L3 and the thrust direction strongly suggests that the non-coaxial character of the D3 deformation was widespread and not limited only to the mylonite zones. In these areas, D1 boudins of pegmatite, leucosome and amphibolite are flattened in S3 and stretched parallel to L3. Asymmetric S1 microlithons between S3 shear planes consistently indicate westward-directed thrusting.

Strike-slip faulting

A complex system of rectilinear brittle vertical WNW- and ENE-trending strike-slip faults, breccia zones and fractures displace the S3 mylonitic foliation and F3 folds. The faults are rarely exposed, but are prominent on aerial photographs and Landsat images. Some of the faults are also delineated on magnetic images as low magnetic zones owing to magnetite destruction. One such fault, a cataclastic fault zone over 20 m wide, separates the Conlara Complex from the structurally overlying Monte Guazú Complex near Cerro Morro in the southwest. At this locality, bodies of the intrusive Achiras Igneous Complex are broken and highly altered by epidote, sericite, hematite and chlorite with rare geothite pseudomorphs after pyrite.

The orientation and conjugate relationship of the WNW- and NE-trending strike-slip faults, breccia zones and fractures indicates possible continuation of the east-west compressive regime that accompanied S3 development. This fracture system is developed throughout the Sierras Pampeanas and in Córdoba, San Luis and La Rioja Provinces where muscovite Ar-Ar ages of micas from quartz veins indicate that this stage began about 385 Ma, peaked at 370 Ma and continued until 355 Ma (Skirrow, 1997b, c). The faults zones therefore represent the final stage of the Achalian Cycle.

3.4 ANDEAN CYCLE

Reverse faulting

During the Cainozoic, tectonism associated with the collision of the Nazca and South American plates resulted in a period of extensional deformation in the Sierras Pampeanas region in the Neogene, followed by compression from the late Neogene through to the present. A marked change in the regional stress field occurred after the mid-Pliocene, coincident with the cessation of volcanism in some areas outside the **3366-18** sheet area.

Since the mid-Pliocene, the Sierras Pampeanas region has been in a compressional regime and the Sierra Comechingones formed by uplift on basement thrusts during this period (e.g. Costa and Vita-Frinzi, 1996). The range slopes gently to the east and is bounded to the west by an escarpment developed on a low to moderate, east-dipping, reverse fault zone (the Comechingones Fault; Costa and others, 1994). Carbon isotopic data (^{14}C ages) suggest the fault was active as recently as 1000 years ago (Costa and Vita-Frinzi, 1996). Immediately south of Papagayos, the main fault zone, which is possibly up to 2 km wide, is exposed in kaolinite quarries within the Uspara Granite. Exposures of the granite are intensely brecciated, altered to chlorite and kaolin and cut by gouge zones dipping 45° to the southeast.

4. GEOMORPHOLOGY

The uplift during the Late Cainozoic of peneplanated crystalline basement on reverse faults, generally trending north-south, produced a series of tilt blocks throughout the Sierras Pampeanas (Jordan and Allmendinger, 1986). The asymmetry of the basement blocks is produced by the formation of steep escarpments on the bounding fault side and gentle slopes, the dissected peneplanated surface, on the other. Broad flat valleys between major blocks are depositional centres filled with a variety of Cainozoic and Quaternary sediments including aeolian, fluvial, and lacustrine material.

The region encompassing the sheet area is comprised of three main physiographic domains: the Sierras de San Luis in the west, the Sierra de Comechingones in the east, and the Conlara Valley in the centre which includes a number of minor ranges and the uplifted basement around the volcanic centre of Sierra del Morro. The principal faults along which uplift occurred are the San Luis and Comechingones Faults which dip to the east. The fault scarps are on the western side of the main sierras and the dissected peneplanated surfaces slope to the east. The broad depositional basin of the Conlara Valley contains the smaller tilt blocks of the Sierras de La Estanzuela, de Tilisarao, del Portezuelo, San Félipe, and del Yulto. The Sierra del Morro is a broad cone of uplifted basement resulting from the intrusion of the volcanic centre.

The Conlara Valley is filled with Cainozoic alluvial, aeolian, and volcanogenic deposits which preserve an earlier Cainozoic surface evidenced by the presence of palaeo-channels found away from present day watercourses. The intermontane deposits in the west of the sheet area are characterised by Quaternary gravels shed from the Sierras de San Luis.

The main drainage from the Sierras de San Luis is via the Río Quinto to the south east, which flows in to the Conlara Valley, and the Río Chorillos to the south west. The Sierras de Comechingones are drained by the east-south east flowing Río Cuarto. The Conlara Valley is drained by the north-north east flowing Río Conlara and the southward flowing Río Rosario.

5. GEOLOGICAL HISTORY

The **3366-18** sheet area forms part of the southern Sierras Pampeanas, comprising basement ranges of Neoproterozoic to early Palaeozoic metamorphic rocks and Palaeozoic granitoids, separated by intermontane Cainozoic sediments. The basement rocks form a series of north-trending lithological and structural domains separated by major mid-crustal shear zones. These domains have been variously interpreted to form originally part of an ensialic mobile belt (e.g. Dalla Salda, 1987) or as terranes that either accreted, or developed on a western convergent margin of the Río Plata craton (e.g. Ramos, 1988; Demange and others, 1993; Escayola and others, 1996, Kraemer and others, 1995, 1996). Recent geochronological studies (e.g. Camacho and Ireland, 1997) indicate that there are two principal domains in the southern Sierras Pampeanas: an older Cambrian domain, and a younger Ordovician domain. Both domains share a common tectonic history since early Ordovician times. Only the older domain is present in the sheet area. The geological history of the sheet area is summarised in Table 2.

5.1 EARLY CAMBRIAN SEDIMENTATION

The oldest rocks in the region form a structurally thick sequence of pelitic and lesser psammitic gniesses which comprise the Conlara and Monte Guazú Complexes. No original sedimentary structures, such as bedding, can be recognised in these metamorphic rocks. Minor marbles are present in the Monte Guazú Complex but are less extensive than in interpreted extensions of the same domains in northern Córdoba (Lyons and others, 1997), where they form semicontinuous belts. These metasediments are interpreted as being deposited on a passive margin, developed during intracontinental rifting and breakup of Laurentia from Gondwana in Eocambrian times at about 540Ma (Dalziel and others, 1994) in a tectonic environment similar to that envisaged by Dalla Salda and others (1992). Lithological similarities and interpreted comparable ages indicate that the metasediments of the Conlara and Monte Guazú Complexes may be correlatives of the Early Cambrian (Aceñolaza and Toselli, 1981) Puncoviscana Formation in the northern Sierras Pampeanas. Such a correlation between the southern and northern Sierras Pampeanas was first postulated by Willner and Miller (1986). The Puncoviscana Formation was interpreted by Dalla Salda and others (1992) to be related to the rift-drift transition during postcollisional Gondwana-Laurentia breakup.

Table 2. Summary of the geological history of the **3366-18** sheet area. Age data and discussion of the various tectonic cycles are presented within the text. The ages of the Pampean Tectonic Cycle are derived from Lyons and others (1997).

Tectonic Cycle	Age (Ma)	Deposition	Deformation	Intrusion
Andean	present	Alluvial, aeolian and talus deposits.	Reverse faulting	
Achalian	~355 404		NW and NE conjugate strike-slip faulting Westerly-directed thrusting, mylonitic foliation (S3), open folding (F3), retrogressive greenschist facies	*I- and S-type granite* Alpa Corral Granite, Uspara Granite, Comechingones Granite, Achiras Igneous Complex (382 Ma)
Famatinian			Mylonitic S2 foliation isoclinal F2 folding, Lower amphibolite/ upper greenschist facies	
Pampean	515 530		Differentiated S1 foliation, isoclinal F1 folding, amphibolite facies	Minor tonalite and mafic rocks
	?540	Sediments of the Conlara and Monte Guazú Complexes		

5.2 PAMPEAN CYCLE

Early Cambrian Deformation, metamorphism, mafic and felsic intrusion

Following intrusion of tholeititic mafic dykes, the sediments of the Monte Guazú and Conlara Complexes were deformed at mid-crustal levels by a compressive event (D1) and metamorphosed at mostly upper amphibolite facies. Uranium-lead dating of zircon rims and monazite formed during this metamorphic event (M1) in Córdoba give an age of ~530 Ma (Lyons and others, 1997; Camacho and Ireland, 1997). This event includes both the D1 and D2 domains of Dalla Salda (1987) and has been previously termed the "Ciclo orogénico Pampeano" (Aceñolaza and Toselli, 1976) or "Ciclo Pampeano" (Dalla Salda, 1987, Toselli and others, 1992). The deformation is interpreted as the first in a series of deformation events associated with convergence on the newly created Pacific Gondwana margin formed after final amalgamation of the supercontinent (eg. Dalziel and others, 1994).

At the closing stages of the Pampean Cycle, an extensive phase of felsic magmatism is evident by widespread subconcordant intrusion of tonalite within the Monte Guazú Complex. There are no radiometric dates on these intrusions, however, in the Sierra Norte - Ascochinga area in Córdoba, similar intrusions, are dated at ~515 Ma (AGSO-Subsecretaría de Minería, unpublished data).

5.3 FAMATINIAN CYCLE

Early Ordovician Deformation, metamorphism

During the Ordovician, closure of the Iapetus Ocean and collision of the Precordillera with the Pampean margin of the Gondwana craton (Dalla Salda and others, 1992, 1996; Dalziel and others, 1996) resulted in amalgamation of the Cambro-Ordovician back arc and the Cambrian basement during a widespread deformational, metamorphic and magmatic event known as the "Ciclo orogénico Famatiniano" (Aceñolaza and Toselli, 1976), Famatinian Orogen (e.g. Dalla Salda and others, 1992) or "Ciclo Famatiniano" (Dalla Salda, 1987). In the Sierra Comechingones region this compressive deformation (D2) reached upper amphibolite grade, and was accompanied by the development of east-dipping ductile shear-zones with, orthogonal westerly-directed thrust movement. Earlier D1 fabrics were openly to tightly folded and locally recrystallised to form a new foliation (S2).

5.4 ACHALIAN CYCLE

Early Devonian granite intrusion and deformation

Mid Palaeozoic resumption of convergence on the western margin of Gondwanaland is evidenced by a widespread compressive deformation in the Cambrian basement rocks, as well as the development of an Early Devonian magmatic arc. The deformation was dominated by orthogonal westerly-directed thrusting with a component of sinistral shearing, both at greenschist facies, and the development of regionally extensive brittle-ductile, conjugate shear-zones. The Las Albahacas Fault Zone formed at this time. Locally, outside the principal shear zones, the basement rocks were open to isoclinally folded and refolded with an axial planar crenulation surface developed in places. Dalla Salda (1987) defined this regional deformation as D3, placing it in the "Ciclo Famatiniano", however, U-Pb and Ar-Ar data (Camacho and Ireland, 1997; Camacho, 1997) indicate this is a discrete event separated from the Famatinian cycle by at least 60 Ma.

Peraluminous to slightly peralkaline felsic melts, generated from partial melting of MgO depleted crustal rocks (Dalla Salda and others, 1995) intruded into the metamorphics discontinuously during and after shear zone development. In the north, coalesced zoned and fractionated plutons comprising the Cerro Aspero Batholith, crosscut the greenschist-facies shear-zones. In other areas, such as farther to the south near Achiras, the La Lajas Shear Zone was the locus of multiply injected subconcordant granite intrusion of the Achiras Igneous Complex. Uranium-lead zircon dating of the Achalian granites suggests that initial plutonism was around 404 Ma (Camacho and Ireland, 1997). Ar-Ar ages from greenschist-facies mylonite zones suggests that deformation continued through until ~355 Ma (Camacho, 1997). The Achalian Cycle probably corresponds to the "Fase Precordilleránica" (Astini, 1996) in the precordillera west of the Sierras Pampeanas where it is related to the amalgamation of the Chilena terrane.

The final stages of the Achalian Cycle were marked by the province-wide development of a complex system of rectilinear brittle-ductile vertical NW- and NE-trending strike-slip faults and fractures. These are well developed in both Monte Guazú Complex and the Cerro Aspero Batholith rocks. The orientation and conjugate relationship of the fractures indicates a continuation of the east-west compressive regime. In other areas, the structures are locally associated with vein-type Au±Cu mineralisation, the result of mesothermal activity interpreted by Skirrow (1997b, c) to be associated with the waning stages of magmatic arc activity as the centre of magmatic activity migrated westward (Ramos and others, 1986). Toselli and others (1996) attribute development of the fracture system to a 355 Ma old "Chánica Orogeny".

5.5 ANDEAN CYCLE

During the Cainozoic, east-west compression resulted in block thrusting of the basement rocks along the Comechingones Fault to form the present north-south oriented range (Sierras Comechingones). The range, like others in the Sierras Pampeanas is bounded to by escarpments developed on moderate to steeply-dipping reverse faults (Jordan and Allmendinger, 1986; Martino and others, 1995; Costa, 1996), many of which show a reactivated and long-lived history. Costa (1996) interpreted most significant movement in the region to have occurred during the Late Pliocene-Pleistocene with further movement continuing during the Quaternary.

SECTION II: ECONOMIC GEOLOGY

By Roger G. Skirrow

1. INTRODUCTION

The 3366-18 1:100 000 scale map area of Provincias de San Luis and Córdoba contains few known metallic mineral occurrences. The only located occurrences are for W and Ag-Pb-Zn, derived from the 1:750 000 scale map of Ricci (1974). The locational accuracy of occurrences from this data source is estimated as ±3000m. Tungsten deposits and anomalous Sn and Mo were also noted by Miró and Zolezzi (1990) and the Secretaría de Minería de La Nación (1994).

As part of the Geoscientific Mapping of the Sierras Pampeanas Cooperative Project, geological and resource data on mineral occurrences in the Sierras de San Luis and Comechingones regions have been compiled in a database (ARGMIN, in MicroSoft Access; Skirrow and Trudu, 1997) using a combination of data from the literature and field data. The principal deposits in most mining districts of the Project area were investigated in the field, with observations subsequently entered into the ARGROC and ARGMIN databases. Petrography of ore and host rock samples (thin sections and polished thin sections) was recorded in a petrographic database (Sims and others, 1996), and selected samples for ore genesis studies were analysed for whole rock geochemistry (Lyons and others, 1996; Lyons and Skirrow, 1996), stable isotopes of oxygen, hydrogen and sulfur (Lyons and and Skirrow, 1996), as well as $^{40}Ar/^{39}Ar$ radiometric age dating (Camacho, 1997). Geographic coordinates were measured by GPS (locational accuracy ±50m), whereas those occurrences not visited in the field were generally located on airphotographs and their geographic coordinates digitised. The locational accuracy for photo-located occurrences is ±200 m. The locations of remaining occurrences are taken from the original data sources, which in some cases allow only very approximate geographic coordinates to be estimated (up to ±3000m).

Mineral occcurrence data are presented in the 1:100 000 scale Metallogenic Map. Output data sheets from the ARGMIN database are appended to this report. Further details on specific mineral deposits may be found in the database. A 1:250 000 Metallogenic Map for the sierras de San Luis and Comechingones shows the mineral occurrences in relation to prospectivity domains (Skirrow, 1997a). The genesis of mineral deposits, metallogeny of the region and discussion of mineral prospectivity are presented in the Economic Geology section of the Report on 1:250 000 scale Geology of the sierras de San Luis and Comechingones (Sims and others, 1997). The principal geological, geophysical and metallogenic model coverages from the GIS of the Sierras Pampeanas (Butrovski, 1997) are presented in summary format (1:400 000 scale) in the *Atlas Metalogenético* (Skirrow and Johnston, 1997).

2. METALLIC MINERAL OCCURRENCES

2.1 W OCCURRENCES AND SN, MO

Only two W occurrences have been located in the map area (Ricci, 1974), both evidently within the Monte Guazú Metamorphic Complex. A regional stream sediment and rock chip geochemical survey covering 400 square kilometres of the Sierra Comechingones in Sheet 3366-18 was reported by the Secretaría de Minería de La Nación (1994) and Miró and Zolezzi (1990). More than 2300 samples were analysed for Cu, Pb, Zn, Sn, W, Mo, Au, Cr, Ni and Co by the EAA method. Tungsten anomalies were outlined in the Cuchilla Blanca (Mina La Oportunidad area, 3600 ppm W) and Quebrada Brava - El Rincon area in association with quartz veins and the Alpa Corral and Comechingones granites. The latter area was determined to be also anomalous in Sn and Cu.

Geochemical anomalies of Sn and Mo were defined in the La Mesada and Cerro Morro - La Tapita areas, evidently quite distant from the main Alpa Corral and Comechingones granite bodies.

Hydrothermal alteration including albitisation, greisen and silicification, and veins containing fluorite, quartz and topaz were noted by Miró and Zolezzi (1990).

Given the spatial association of particularly W geochemical anomalies with the Alpa Corral and Comechingones granites, it is likely that at least the W enrichments and possibly Sn and Mo are related to Achalian magmatism.

2.2 AG-PB-ZN OCCURRENCES

Two Ag-Pb-Zn occurrences were shown on the map of Ricci (1974) in this region of the Sierra de Comechingones, both apparently within the Monte Guazú Metamorphic Complex.

3. NON-METALLIC MINERALS

3.1 QUARTZ, MICA, FELDSPAR

Numerous small deposits of quartz, mica and feldspar have been worked from pegmatites in the Sheet area.

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ARGMIN

MINERAL DEPOSIT DATABASE

OUTPUT DATA SHEETS

ARGMIN - Argentinian Mineral Deposits -

ARGMIN NO: 445 **Deposit:** **Clelia**

Synonyms: CR-003

Operating Status:

Deposit Expression:

Field Checked: No

Exposed:

Field ID: 387

LOCATION

Latitude:	32.923800 S	**Longitude:**	64.934300 W
Easting:		**Northing:**	
Location Method:	non-standard geological map	**Accuracy (m):**	3000
Province:	CORDOBA	**Department:**	Río Cuarto
Geological Region:	Sierras Pampeanas	**Geographic Area:**	CR-003
Location Description:	Clelia		
1:250 000 Sheet No:	3366-II	**1:250 000 Sheet Name:**	Santa Rosa
1:100 000 Sheet No:	18	**1:100 000 Sheet Name:**	3166-18

Location/deposit Reference: 98 Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera

COMMODITIES

Commodity	Production	Month/Year	Resources	Grade	Total Commodity	Comments
Ag						
Pb						
Zn						

DEPOSIT FEATURES

Classification: unknown

Relationship to host rocks:

Ore Controls:

Modification to deposit:

Age of mineralisation, Method:

Comments:

Mineralisation: *Style:*

Texture:

Mineralogy: *Ore:*

Gangue:

Orientation: *Dip:* *Plunge:* *Strike:*

Shape:

References

ARGMIN Originator: A.G. Trudu

Entry Date: 2-Jun-1995

Ref. ID	Other ID	Reference
98		Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera

ARGMIN - ARGENTINIAN MINERAL DEPOSITS: Santa Ana -

ARGMIN NO: 446 **Deposit:** Santa Ana

Operating Status:

Field Checked: No

Field ID: 384

Synonyms: CR-004

Deposit Expression:

Exposed:

LOCATION

Latitude: 32.904200 S

Easting:

Location Method: non-standard geological map

Province: CORDOBA

Geological Region: Sierras Pampeanas

Location Description: Santa Ana

1:250 000 Sheet No: 3366-II

1:100 000 Sheet No: 18

Longitude: 64.840400 W

Northing:

Accuracy (m): 3000

Department: Río Cuarto

Geographic Area: CR-004

1:250 000 Sheet Name: Santa Rosa

1:100 000 Sheet Name: 3166-18

Location/deposit Reference: 98 Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera

COMMODITIES

Commodity	Production	Month/Year	Resources	Grade	Total Commodity	Comments
Ag						
Pb						
Zn						

DEPOSIT FEATURES

Classification: unknown

Ore Controls:

Age of mineralisation, Method:

Comments:

Mineralisation: *Style:*

Texture:

Mineralogy: *Ore:*

Gangue:

Orientation: *Dip:* *Plunge:* *Strike:*

Shape:

Relationship to host rocks:

Modification to deposit:

References

ARGMIN Originator: A.G. Trudu

Entry Date: 2-Jun-1995

Ref. ID	Other ID	Reference
98		Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera

ARGMIN - ARGENTINIAN MINERAL DEPOSITS: Joseina -

ARGMIN NO: 448 **Deposit:** **Joseina**
Synonyms: CR-006
Operating Status:
Deposit Expression:
Field Checked: No
Exposed:
Field ID: 418

LOCATION

Latitude: 32.874900 S
Longitude: 64.893700 W
Easting:
Northing:
Location Method: non-standard geological map
Accuracy (m): 3000
Province: CORDOBA
Department: Río Cuarto
Geological Region: Sierras Pampeanas
Geographic Area: CR-006
Location Description: Joseina
1:250 000 Sheet No: 3366-II
1:250 000 Sheet Name: Santa Rosa
1:100 000 Sheet No: 18
1:100 000 Sheet Name: 3166-18
Location/deposit Reference: 98 Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera

COMMODITIES

Commodity	Production	Month/Year	Resources	Grade	Total Commodity	Comments
W						

DEPOSIT FEATURES

Classification: unknown
Relationship to host rocks:
Ore Controls:
Modification to deposit:
Age of mineralisation, Method:
Comments:
Mineralisation: *Style:*
Texture:
Mineralogy: *Ore:*
Gangue:
Orientation: *Dip:* *Plunge:* *Strike:*
Shape:

References

ARGMIN Originator: A.G. Trudu
Entry Date: 2-Jun-1995

Ref. ID	Other ID	Reference
98		Ricci, S.M., 1974, Provincia de Córdoba - Mapa Minero, Escala 1:750 000, Ministero de Indústria Y Minería, Subsecretería de Minería, Dirección Nacional de Promoción Minera