Report on

1:100 000 Scale Geological and Metallogenic Maps
Sheet 3163-13 JESUS MARIA

Province of Córdoba

Peter G. Stuart-Smith and Roger G. Skirrow

GEOSCIENTIFIC MAPPING OF THE SIERRAS PAMPEANAS ARGENTINA-AUSTRALIA COOPERATIVE PROJECT

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

1997

CONTENTS

SECTION 1: GEOLOGY

SECTION 1: GEOLOGY

by Peter G. Stuart-Smith

1. INTRODUCTION

1.1. LOCATION AND ACCESS

The Jesús María 1:100.000 Sheet area lies within the Córdoba Province, between 30°40'-31°00'S and 64°00'-64°30'W. The area is part of the 3163-I (Jesús María)1:250 000 sheet area.

The region includes the northern extremities of the Sierra Chica one of several north-trending mountain ranges which traverse the northern part of the Córdoba Province. The Sierra Chica is drained by the easterly flowing Ríos Ascochinga, Santa Sabina, and Pinto.

Access to the region, from Córdoba city, is via Jesús María and Ruta Provincial 9 in the east. Two unsealed roads traverse the Sierra Chica, one passing, through Ascochinga and the other through Todos Los Santos.

1.2. NATURE OF WORK AND PREVIOUS INVESTIGATIONS

Mapping of the Jesús María area 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 Subsecretaria de Mineria (DNSG) (Figure 1.1). Only the southern three quarters of the sheet (below

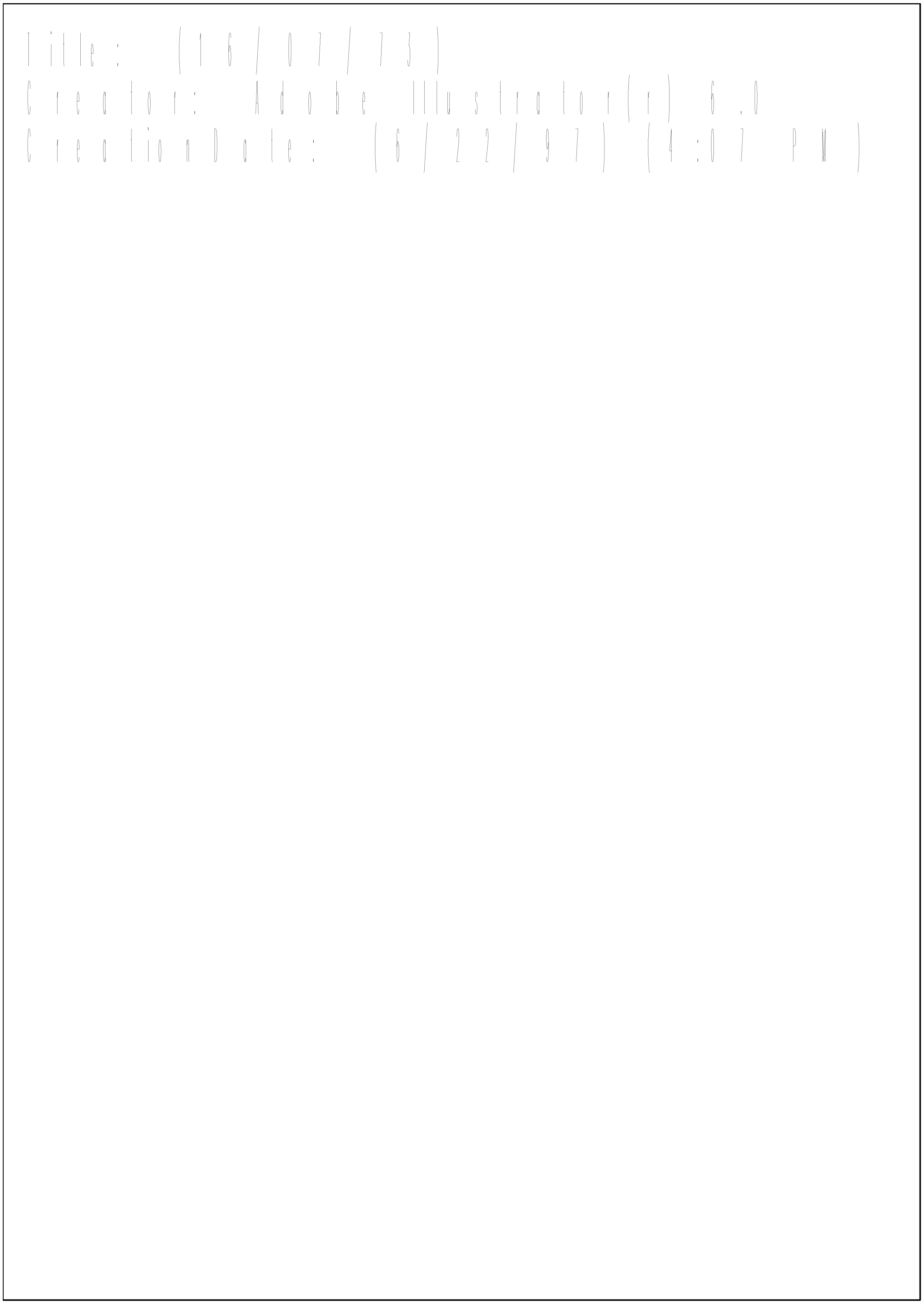

Figure 1.1. Location and simplified geology of the Sierras septentrionales de Córdoba and location of 1:100 000 sheets.

30°45′) was covered by the mapping program. The mapping employed a multidisciplinary approach using the 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 Jesús María geological map was compiled on topographic bases produced at photo-scale from rectified Landsat images controlled by field GPS sites. Relief data was obtained from the digital terrane model (DTM) acquired during the airborne geophysical survey.

Geologists involved in the fieldwork were P.G. Stuart-Smith and P. Lyons,(AGSO), and J.C. Canadiani, H. Lopez, and R. Miro (DNSG)and B. Torres (Secretaría de Minería de la Provincia de Córdoba) assisted with the fieldwork.

Much of the area was first mapped as undifferentiated metamorphic basement by early workers (e.g. Riman, 1918; Pastore, 1932; Pastore and Methol, 1953). Later workers (e.g. Michaut, 1986; Perez and others, 1996) recognised that many of the gneisses were originally intrusive granitic rocks, separating them from other (para) gneiss and marble. Perez and others mapped the granitoids east of the Carape Fault in the Sierra Chica, correlating them with the granitic batholith in the Sierra Norte.

2. STRATIGRAPHY

2.1. GENERAL RELATIONS

The Jesús María area is part of the southern Sierras Pampeanas, a distinct morphotectonic province of early to mid Palaeozoic metamorphic, felsic and mafic rocks, forming a series of block-tilted, north-south oriented ranges separated by intermontane basins (Figure 2.1).

Title: (72illus.eps)
Creator: Adobe Illustrator(r) 6.0
CreationDate: (6/24/97) (11:48 AM)

Figure 2.1. Location of the three project areas of the Argentina-Australia Cooperative Project and simplified regional geology of the southern Sierras Pampeanas.

The 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 as part of 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 and structural domains separated by major tectonic zones. There are two principal domains: a Cambrian Pampean domain, and the Ordovician Famatinian domain to the west. Both domains have shared a common geological history since early Ordovician times. The boundary between the domains is broadly coincident with a regional change in the gravity near the western flank of the Sierras de Córdoba (Miranda and Introcaso, 1996) and is marked by the Río Guzman Shear Zone further south in the Province of San Luis. Only the Pampean domain is exposed in the Sierras Chica and the Jesús María area. The younger Famatinian domain is inferred to be present in the subsurface west of the Sierra Grande.

In the Jesús María area, basement consists of Early Cambrian metamorphic and igneous complexes intruded by Cambrian and Devonian granitoids. The remnants of continental Cretaceous sediments and rare volcanics cap the summit of the Sierra Chica, and together with Tertiary, and Quaternary sediments occupy major valleys and intramontane areas, particularly in the east.

A summary of stratigraphy and relations is given in Table 2.1.

Table 2.1. Summary of stratigraphy and relationships in the Jesús María 1:100 000 sheet.

Age (Ma)	Unit	Description	Relations
CAINOZOIC QUATERNARY	Talus deposits.	Unconsolidated debris of granitic rocks derived from the Capilla del Monte Granite	Deposits along the fault scarp of Cerro Uritorco
	Alluvium	Unconsolidated clay, sand and gravel	Deposits along active river courses
	Fluvial fans	Unconsolidated bouldery gravels	Interfinger with alluvial deposits
TERTIARY TO QUATERNARY	Undifferentiated fluvial and aeolian deposits	Clay, sand, gravel, paleosol	Mantles older units.
	Fluvial fan deposits	Unconsolidated gravel	Raised deposits along base of Cainozoic fault scarps.
MESOZOIC	Saldán Formation	Polymictic conglomerate, coarse-grained poorly sorted clastic sediments	Unconformably overlies metamorphic basement and granitic rocks
	Los Terrones Conglomerate	Polymictic conglomerate, feldspathic lithic quartz arenite	Unconformably overlies metamorphic basement and granitic rocks
	Rosario Conglomerate	Polymictic conglomerate, lithic arenite, basalt	Unconformably overlies metamorphic basement and granitic rocks
DEVONIAN	Capilla del Monte Granite	Monzogranite	Intrudes La Falda Complex and El Manzano Formation
CAMBRIAN	Güiraldes Tonalite	Leuco-tonalite, leuco-granodiorite, leuco-monzogranite	Intrudes La Falda Complex and El Manzano Formation
	Ascochinga Complex	Hornblende tonalite, biotite granodiorite, biotite granite, megacrystic biotite granite, granitic ortho-gneiss, banded para-gneiss, tonalitic orthogneiss, meta-gabbro, meta-diorite	Faulted against El Manzano Formation.
	La Falda Complex	Banded pelitic gneiss, leuco-tonalitic ortho-gneiss, marble, and calc-silicate rocks	Faulted against El Manzano Formation. Intruded by Güiraldes Tonalite and Capilla del Monte Granite
	El Manzano Formation	Pelitic gneiss, marble, calc-silicate rock, and amphibolite	Faulted against Ascochinga and La Falda Complexes. Intruded by Güiraldes Tonalite.

2.2. EARLY PALAEOZOIC METAMORPHIC BASEMENT

El Manzano Formation (∈lm)

Pelitic gneiss, marble, calc-silicate rock, and amphibolite

A one to three kilometre-wide fault-bounded belt of interlayered paragneiss, marble and amphibolite extends from El Manzano (from which it derives its name although El Manzano is south of the sheet area) to north of Cerro Uritorco. This unit, here referred to as the El Manzano Formation, has previously been mapped by early workers (e.g. Riman, 1918; Pastore, 1932; Pastore and Methol, 1953) as part of undifferentiated basement metamorphics which are now subdivided into the El Manzano Formation and the La Falda Metamorphic Complex. The formation is distinguished from the metamorphic complex by the absence of tonalite and the greater abundance of marble and calc-silicate rocks. It is well-exposed throughout its length, and Provincial Route 66, from Ascochinga to La Cumbre, provides an almost continuous transect through the central portion of the unit.

The El Manzano Formation is faulted against the Ascochinga Igneous Complex to the east and the Güiraldes Tonalite and La Falda Metamorphic Complex to the west, except where concordant contacts are inferred. Intrusive contacts are also interpreted for part of the ?Cambrian Güiraldes Tonalite. The Devonian Capilla del Monte Granite intrudes the northern part of the formation with sharp discordant contacts and numerous quartz - K-feldspar pegmatite dykes of undetermined age also intrude the unit. Further north, it is covered by the Cretaceous Los Terrones Conglomerate and unconsolidated Quaternary deposits. Both the La Falda Metamorphic Complex and the El Manzano Formation share a common structural and metamorphic history and are interpreted as Early Cambrian in age.

The dominant lithology is *para-gneiss* which comprises about half the unit, and is interlayered with marble and calc-silicate rocks, and minor amphibolite. The gneiss, derived from a pelitic protolith, is typically a dark grey muscovite-biotite-quartz K-feldspar banded rock with minor sillimanite. A penetrative gneissic foliation is defined by mineralogically differentiated bands of micas and medium- to coarse-grained granoblastic quartz and feldspar leucosome.

Marble and *calc-silicate rocks* crop out as low strike ridges. They are normally banded white, green, grey or pink and form layers up to 2 m thick. Medium- to coarse-grained granoblastic calcite-dolomite is the most common mineral present with varying amounts of chondrodite, scapolite, grossular, clinozoisite, diopside, titanite, plagioclase, K-feldspar, quartz, and apatite. Banding parallels a weak to strong gneissic foliation marked by aligned silicate minerals (where present) and probably represents tectonically transposed lenses formed during the Pampean medium- to high-grade deformation event.

Amphibolite bands, up to 10 m across, are commonly interlayered with marble and calc-silicate rocks. They are a dark green, foliated and banded rock composed essentially of hornblende, plagioclase and quartz with minor secondary epidote and chlorite.

The El Manzano Formation is the northernmost of a number of similar faulted-bounded belts of marble-rich sequences which occur throughout the Sierras de Córdoba. Other examples are: the Quilpo Formation west of the Jesús María Sheet; and in the Sierra Comechingones where the southernmost of these is distinguished as the Las Lajas Complex. Like the latter complex, the El Manzano Formation was probably fault-emplaced during either the Ordovician Famatinian or the Devonian Achalian deformation event. These units may represent originally separate sequences or dismembered parts of a once continuous sedimentary package of platform carbonates and pelites, and possible mafic rocks deposited during the Early Cambrian.

La Falda Metamorphic Complex (∈fgn, ∈sgn)

Banded pelitic gneiss, leuco-tonalitic ortho-gneiss, marble and calc-silicate rocks

The La Falda Metamorphic Complex lies between two separate north to north-west-trending largely fault-bounded carbonate-rich metamorphic units of the El Manzano Formation in the Sierra Chica and the Quilpo Formation to the west of the sheet area, near San Marcos Sierra. Several granitic plutons and smaller bodies intrude the complex and include the ?Cambrian Güiraldes Tonalite and the Devonian Capilla del Monte Granite in the Jesús María sheet area. In the west, along the Punilla Valley, the unit is covered by unconsolidated Quaternary coarse clastic deposits, and in the central and southern parts of the Sierra Chica, remnant deposits of the Cretaceous Rosario Conglomerate unconformably overlie parts of the complex.

The La Falda Metamorphic Complex is distinguished from the El Manzano Formation by the presence of tonalite and a smaller proportion carbonate rocks but shares a common structural and metamorphic history and is, thus, Early Cambrian. Numerous aplite and muscovite - quartz - K-feldspar pegmatite dykes, up to 10 m wide, intrude the unit. These occur particularly within 2 km of the Güiraldes Tonalite in the Sierra Chica.

The complex consists mostly of pelitic gneiss with about 20% interlayered leucotonalitic ortho-gneiss and very minor marble and calc-silicate rocks. Rare amphibolite boudins probably represent meta-mafic dyke rocks. The complex is subdivided into two sub-units based on the predominance of either pelitic gneiss or ortho-gneiss. The ortho-gneiss - rich portion, mapped as the San Marcos Formation by Massabie (1982), is not present in the sheet area.

Grey *banded muscovite-biotite-feldspar-quartz-garnet ±sillimanite gneiss* (∈fgn) is the predominant rock type. Cordierite is also present within contact aureole surrounding the Capilla del Monte Granite where it occurs as porphyroblasts. Feldspar contents range from 10% to 20% with plagioclase predominating over K-feldspar. The rock is typically gneissic and migmatitic, in places, with leucosome bands of quartz-feldspar. The rock is interpreted as a meta-pelite and is indistinguishable from pelitic gneiss in the El Manzano Formation.

Buff to pale *grey medium-grained equigranular muscovite-biotite leuco-tonalitic ortho-gneiss* (∈sgn) forms lenses within pelitic gneiss, ranging from less than a metre to several metres wide. Quartz contents are uniformly high (40%-45%) with some variation in proportional feldspar content. Zircon is the only common accessory phase. Locally, their composition is a leuco-monzogranite. In places, the ortho-gneiss truncates the main S1 metamorphic differentiated fabric, enclosing rotated enclaves of pelitic gneiss. Both the pelitic and ortho- gneisses are isoclinally folded by F2 with the ortho-gneiss extended within the S2 foliation plane. Biotite folia within the ortho-gneiss are continuos with S2 and S1 foliations in the pelitic gneiss. These relationships indicate that the ortho-gneiss originally intruded the pelitic gneiss at the close of the Early Cambrian Pampean deformation (D1) prior to the Early Ordovician Famatinian deformation (D2).

Very minor *marble and calc-silicate rocks* are interlayered with pelitic gneiss. They are composed of recrystallised calcite-dolomite with common grossular, quartz and epidote.

Ascochinga Igneous Complex (∈at, ∈agd, ∈ag1, ∈ag2, ∈agn1, ∈agn2, ∈ao)
Hornblende tonalite, biotite granodiorite, biotite granite, megacrystic biotite granite, granitic orthogneiss, banded paragneiss, tonalitic orthogneiss

East of the Carape Fault, in the Sierra Chica, deformed Early Cambrian granitic rocks and minor metamorphics are distinguished as the Ascochinga Igneous Complex. The complex was first mapped as undifferentiated metamorphic basement by early workers (e.g. Riman, 1918; Pastore, 1932; Pastore and Methol, 1953). Later workers (e.g. Michaut, 1986; Perez and others, 1996) recognised that many of the gneisses were originally intrusive granitic rocks, separating them from other paragneiss and marble. Perez and others mapped the granitoids east of the Carape Fault as either "Pluton Ascochinga" or "Pluton Estancia Veija" and correlated them with the granitic batholith in the Sierra Norte. Here both units of Perez and others have been incorporated into the Ascochinga Igneous Complex, which is subdivided into seven informal sub-units based on the dominance of a particular lithology. All the phases described by Perez and others are recognised, in addition to a foliated granite sub-unit and an interlayered para- ortho-gneiss sub-unit which broadly corresponds to the “Pluton Estancia Veija” as mapped by Perez and others (1996).

Outcrop of the complex is good in the west but is poorer on the eastern flanks of the Sierra Chica. Subdivision of the complex is based mainly on interpretation of aeromagnetic and gamma-ray spectrometric patterns, consequently most boundaries within the complex are approximate. In the field, contacts between sub-units are often gradational. Aeromagnetic anomalies also indicate continuity of the complex to the east of Jesús María township and with the Sierra Norte to the north, which contains all the main granitoid phases recognised in the Ascochinga Igneous Complex (R. Miró personal communication, 1996).

Relationships between the Ascochinga Igneous Complex and other Paleozoic units are poorly known. Granitoid units within the complex intrude minor bodies of para- and ortho-gneiss with contacts mostly concordant to the differentiated metamorphic fabrics. However, they display only variably developed foliations indicating late syntectonic emplacement with respect to the S1 fabrics in paragneiss. Minor dykes of undeformed pegmatite, aplite and lamprophyre intrude the complex. Within gneissic enclaves, boudinaged bodies of amphibolite, less than 2 m long, may represent deformed early mafic dykes. Contacts with other basement units are fault-bounded. The western extent of the complex is limited by the east-dipping Carape Fault where it is thrust over the El Manzano Formation to the west. In the north, Cretaceous sediments of the Los Terrones Conglomerate unconformably overly the unit, and in the east, unconsolidated Mesozoic and Cainozoic sediments onlap basement rocks.

The age of the Ascochinga Igneous Complex is interpreted as Early Cambrian, based on a U-Pb zircon dating of granite from the Sierra Norte which yielded an age around 514 Ma (U-Pb zircon SHRIMP analyses, unpublished data). This age is consistent with ages of about 515 Ma to 520 Ma for the El Pilón Granite (Rapela and others, 1995; Camacho and Ireland, 1997) near Villa de Soto and about 530 Ma for peak M1 metamorphism in the Sierras de Córdoba (Camacho and Ireland, 1997). This deformation, metamorphism and magmatism defines the Pampean cycle in the Sierras Pampeanas.

Grey medium- to coarse-grained biotite hornblende tonalite (∈at) is the principal lithology, cropping out mainly in the west, where it forms the bulk of the pluton. Although mostly tonalitic in composition, the rock ranges through granodiorite, monzogranite, monzonite and monzodiorite. Perez and others (1996) recognised three facies: the "Facies tonalitica hornblendifera, tonalita biotita, and tonalita porfiritica". However, these facies could not be mapped during the current program as contacts between them are gradational and their distribution could not be distinguished on either aerial photographs, Landsat TM images, or on the basis of magnetic and gamma-ray spectrometric properties. Textures vary from equigranular to seriate with minor pink K-feldspar crystals up to 2 cm across. Biotite contents range from 5 to 15% with hornblende up to 25%. Titanite, zircon, apatite, allanite and magnetite are common accessories. A characteristic of this phase is its high magnetic susceptibility, mostly greater than 500 x 10^{-5} SI, and the abundance of mafic-rich xenoliths and enclaves (diorite and amphibolite) and biotite/hornblende schlieren. Minor metasedimentary xenoliths are present near contacts. A variably developed gneissic foliation dips moderately to the east and is defined by aligned biotite and hornblende. Primary quartz and feldspar grains are deformed with some recrystallised polygonal mosaic development The foliation becomes a penetrative mylonitic foliation within 500 m of the Carape Fault where it forms shear planes with a steeply pitching mineral lineation. All rocks show minor late epidote, sericite and carbonate alteration of plagioclase and marginal chloritisation of biotite. Haematite is present in late fractures.

Buff to grey *biotite granodiorite* (∈agd) is the second most abundant phase. It is occurs in two main bodies, one south-west of Ascochinga and the other occupying most of the complex between Ascochinga and Ongamira. The granodiorite is medium- to coarse-grained, and equigranular to rarely seriate with pink microcline subhedra up to 2 cm across. Titanite, apatite, allanite and magnetite are accessory minerals and rare hornblende may be present. The granodiorite is distinguished from the main phase by the lack of hornblende and mafic xenoliths and a lower magnetite content (magnetic susceptibilities are less than 100 x 10^{-5} SI). The slightly higher potassium content of the rock compared with the overall more tonalitic main phase, is reflected in gamma-ray spectrometric images and was one of the main criteria used to map the full extent of the sub-unit. The phase corresponds to the “Facies granodioritica” distinguished by Perez and others (1996).

Massive pink medium- to coarse-grained *biotite granite* (∈ag1) occupies the eastern part of the complex, forming several bodies often enclosed by biotite granodiorite or hornblende tonalite phases. The principal bodies are in the north near San Pelegrino, immediately west of Santa Catalina, south-east of Ascochinga and near Jesús María township. This granite is the least deformed and most felsic phase of the complex and may be the youngest, as it intrudes the more mafic phases. Where observed, contacts are sharp and intrusive. Metasedimentary gneiss xenoliths are common in the north near Todos Los Santos. The granite is mostly equigranular and coarse-grained with seriate and porphyritic textures in some medium-grained varieties. In the latter, pink microcline feldspar forms phenocrysts up to 1 cm across. Common accessory minerals include apatite, zircon, magnetite and garnet. Compositionally the granite lies across the syenogranite, monzogranite and quartz syenite fields. Minor fine-grained muscovite is present as rare primary grains and as an alteration mineral intergrown with haematite and epidote marginal to biotite grains. Very weak sericite and epidote alteration is also ubiquitous. Magnetic susceptibilities are low ($<100 \times 10^{-5}$ SI) except where the granite forms small intrusive bodies within the more strongly magnetic tonalite. In such cases, raised magnetic susceptibilities may be attributed to contamination from the adjacent tonalite. Its peraluminous composition indicates a different source to all other granitoids in the complex which were derived from igneous sources.

Pink coarse-grained megacrystic biotite granite,(∈ag2) the “Facies de granitos porfiricos” of Perez and others (1996), forms an irregular-shaped pluton in the northeast near Cañada de Río Pinto and numerous small bodies, mostly undifferentiated, within biotite hornblende tonalite and biotite granodiorite throughout the complex west and south of Ascochinga. A characteristic of the granite is abundant pink tabular to rounded K-feldspar megacrysts ranging from 4 to 10 cm across. Zircon, apatite, magnetite, titanite and allanite are common accessories and rare hornblende may be present as inclusions in plagioclase. Biotite, comprising over 10% of the rock, forms decussate aggregates which are deformed and foliated in places, defining a weak to strong gneissic foliation. Minor mafic xenoliths and schleiren, flattened in the foliation plane, are common. Late alteration includes weak sericitisation and carbonation of plagioclase, chloritisation of biotite and minor secondary epidote, haematite and muscovite. Abundant magnetite is reflected by high magnetic susceptibilities mostly greater than 500 x 10^{-5} SI.

Pink biotite granitic orthogneiss (∈agn1) is the least common sub-unit in the complex, forming screens separating interlayered banded muscovite paragneiss and tonalitic orthogneiss from other granitoids in the El Sauce area in the centre and near Todos Los Santos in the north. The granitic gneiss is medium-grained and equigranular with a penetrative gneissic foliation defined by biotite schleiren and bands. Minor hornblende occurs in places and magnetic susceptibilities are highly variable. In the vicinity of El Sauce, the gneiss contains several amphibolite enclaves and the original intricate discordant contacts are preserved. Contacts with the interlayered paragneiss and tonalitic gneiss are concordant and appear to be gradational with other units such as the main body of biotite granodiorite between El Sauce and Ascochinga. Perez and others (1996) included the sub-unit in the "Pluton Estancia Vieja", distinguishing a "Facies de ortogneises graniticos".

Interlayered *banded muscovite biotite quartz feldspar paragneiss* and lesser *tonalitic orthogneiss* (∈agn2) are the oldest rocks in the complex, forming either screens between, or enclaves within, the different intrusive granitoid phases. Together they constitute about 10% of the complex with the largest body covering about 30 km^2 north of the Río Santa Sabina between Bajo Los Olmos and Colonia Hogar. Both rock types were mapped as "Pluton Estancia Veija" by Perez and others (1996). The banded paragneiss typically contains about 50% feldspar and 30% to 40% quartz, rare garnet and detrital rounded zircon. Contact metamorphic sillimanite and cordierite are also present within smaller enclaves. The fabric is gneissic with a pronounced compositional banding marked by alternate fine-to coarse-grained granoblastic polygonal quartz -feldspar leucosome and mica-rich folia. The orthogneiss forms concordant layers within the banded paragneiss, ranging from a few metres to tens of metres thick. It is tonalitic in composition with about 60% coarse-grained subhedral albite, lesser quartz and minor K-feldspar. Weakly aligned biotite and minor intergrown muscovite form decussate aggregates and define the gneissic foliation, paralleling that in the banded paragneiss. Titanite, apatite, allanite and magnetite are common accessory minerals in the orthogneiss. Both rocks have very weak sericitic and haematitic alteration with minor epidote and chlorite alteration also in the orthogneiss.

Although, superficially, the interlayered paragneiss-orthogneiss sequence is similar to the La Falda Metamorphic Complex to the west, it is distinguished from the La Falda Metamorphic Complex by a greater feldspar content in the Ascochinga Igneous Complex paragneiss (50% compared to less than 20% in the La Falda Metamorphic Complex) and the elevated magnetic susceptibility (magnetic susceptibility >500 x 10^{-5} SI) and metaluminous composition of the orthogneiss (the La Falda Metamorphic Complex tonalitic orthogneisses are peraluminous and non-magnetic).

Enclaves and xenoliths of dark greenish grey, medium- to coarse-grained, equigranular *meta-gabbro, meta-diorite* and *meta-quartz diorite,* (∈ao) are very common in the metaluminous phases, in particular, within biotite granodiorite and hornblende tonalite. The largest body, about 1 km across, crops out at El Sauce in the centre of the complex where intrusive contacts with the enclosing granitic orthogneiss are exposed. The rock is strongly magnetic (magnetic susceptibilities >1500 x 10^{-5} SI) and another larger body at depth, is interpreted to be the source of a magnetic anomaly centred south of Los Molles between La Granja and Jesús María township. The gabbro and diorites are composed essentially of subhedral plagioclase, hornblende, biotite and minor quartz, magnetite and trace amounts of apatite and pyrite. In meta-gabbro, ophitic textures are preserved in hornblende replacements of clinopyroxene. The enclaves and xenoliths are mostly foliated with some metamorphic compositional banding. Late epidote, chlorite and sericite alteration is common particularly near contacts with the enclosing rocks.

The Ascochinga Igneous Complex is an Early Cambrian meta-intrusive complex comprising rocks of a diverse chemical character and origin, including tholeiitic mafic enclaves, peraluminous granite, and metaluminous tonalite, granodiorite and granite. These latter rocks are the most extensive units, forming a fractionated composite batholith which is contiguous with the compositionally and texturally similar granitoids to the north in the Sierra Norte (Perez and others, 1996; Lira and others, 1996). They are interpreted to have formed in a continental magmatic arc setting (Lira and others, 1996). Major and trace element geochemistry shows that the granitoids are typically medium-K calc-alkaline with FeO*/MgO ~ 2, La/Yb ~ 10, and have slight depletion of MREE and small to absent negative Eu-anomalies (Rapela and Pankhurst, 1996). Initial 87Sr/86Sr ratios are mostly in the range 0.708 to 0.711, with Ndt -4 to -5, indicating involvement of older crust (Rapela and Pankhurst, 1996).

2.3. PLUTONIC ROCKS

Güiraldes Tonalite (∈tg)

Leuco-tonalite, leuco-granodiorite and leuco-monzogranite

Leuco-granitoids cropping out along the Sierra Chica between Capilla del Monte and east of La Falda are included in the Güiraldes Tonalite. The unit includes both the “Pluton Güiraldes” and the “Tonalita La Cumbre” of Pérez and others (1996). There are no distinct compositional or relational differences between the plutons mapped by Pérez and others. Saieg (referred to by Pérez and others, page 501) described the contact between the two as transitional. The limit of the Güiraldes Tonalite is poorly defined, particularly in the south, owing to intricate intrusive contacts and numerous enclaves of the surrounding La Falda Metamorphic Complex. There is no magnetic (magnetic susceptibilities are low: about 20 x 10^{-5} SI) or gamma-ray spectrometric contrast between the granite and the complex. The tonalite may well represent a larger body of the intrusive tonalites found within the La Falda Metamorphic Complex, correlating with rocks west of Capilla del Monte mapped as the San Marcos Formation by Massabie (1982).

The Güiraldes Tonalite forms irregular to elliptical-shaped bodies enclosed by the La Falda Metamorphic Complex and to a lesser extent the El Manzano Formation. These bodies are displaced and faulted against the El Manzano Formation to the east which forms a continuous faulted belt thrust over units to the west. Enclaves of marble, amphibolite and gneiss, up to 1 km across, are common throughout.

Intrusive contacts with the enclosing units are also exposed at several localities such as 30.963°S, 64.409°S, about 10 km east of La Cumbre, where an east-trending concordant contact with layered marble of the El Manzano Formation is exposed. Pegmatite forms an irregular semicontinuous border zone up to 2 m wide along the tonalite margin with little contact effects on marble other than minor recrystallisation. About 1 km east of the telecommunication towers at Los Cocos, a north-south contact with La Falda Metamorphic Complex gneiss to the west is well-exposed in several quarries. This contact is intrusive and irregular in places, crosscutting medium-grade metamorphic differentiation fabrics. Mostly, the contact is planar and parallel to a low-grade penetrative foliation in the tonalite and gneiss which, in the latter, post-dates the gneissic foliation. Minor pegmatite veins occur in tension gashes indicating reverse (east-side up movement) along the contact.

Late-stage quartz, aplite and muscovite-quartz-feldspar pegmatite veins are common throughout the tonalite and immediately adjacent metamorphics (within two kilometres). They are folded and deformed by the regional open folding above. The localisation of pegmatite, at both the contact localities described above, in low-strain zones associated with the regional folds, indicates syn-tectonic emplacement.

The dominant lithology is a pale grey to pink, *medium- to coarse-grained, muscovite biotite equigranular leuco-tonalite* with lesser *leuco-granodiorite and leuco-monzogranite*. Apatite is a common accessory phase and rare garnet is present in highly fractionated phases near contacts. A weak, but pervasive, NNW-trending foliation is widely developed particularly along pluton margins. The foliation has a moderate to steep dip (60°-85°) to the ENE and is axial planar to broad regional tight folds. The foliation comprises weakly aligned deformed primary muscovite and biotite primary grains, with minor secondary sericite folia and weak chlorite epidote alteration of biotite. Plagioclase subhedra are typically deformed and quartz is strained with sutured grain-boundaries and some ribbon aggregates. This low-grade metamorphic fabric is the same as that present in the Ascochinga Igneous Complex and is probably Early Ordovician (Famatinian) in age.

The granitoids comprising the Güiraldes Tonalite are strongly peraluminous with ASI > 1.1 (S-type of Chappell and White, 1974), low K_2O and HFSE contents (~1%), initial 87Sr/86Sr of 0.7065 and a εNdt of about -4 (Rapela and Pankhurst, 1996). Pérez and others (1996) interpreted the pluton to be related to the metaluminous granites of the Ascochinga Igneous Complex and interpreted them as forming in a magmatic arc setting. Rapela and Pankhurst suggested their genesis involved high-pressure melting of primitive mafic rocks that had undergone relatively recent depletion in lithophile element content.

Capilla del Monte Granite (Dgm1)

Monzogranite

The Capilla del Monte Granite, named by Riman (1918), has been described by Massabie (1982) and Murra and Baldo, 1996). The eastern part of granite is well exposed as rocky crags on the summit of Cerro Uritorco in the far north-west of the Jesús María sheet area. Talus slopes mantle the mountain's steep western flank. Magnetic anomaly patterns indicate that the granite forms a roughly circular pluton, about 10 km across extending into the adjoining sheet area to the west.

The granite intrudes Cambrian metamorphic rocks of the La Falda Metamorphic Complex and the El Manzano Formation to the east with smooth discordant contacts. The eastern portion of the contact at Cerro Uritorco dips shallowly eastwards with embayments and outliers of metamorphics forming a thin capping over parts of the pluton. The granite post-dates both the Pampean and Famatinian deformations but has some development of the conjugate north-west - northeast-trending fracture set which characterises the later part of the Devonian Achalian deformation. K-Ar age determinations indicate a minium age of 345±10 Ma for the pluton (Massabie, 1982).

The pluton is a massive *pink coarse-grained biotite muscovite monzogranite*. Two textural varieties are distinguished, a dominantly equigranular phase (Dgm1) and a porphyritic border phase (Dgm2). The latter phase has not been distinguished in the sheet area. Where porphyritic, microcline forms phenocrysts up to 7 cm across. Zircon and apatite are accessory phases. Murra and Baldo (1996) describe three varieties of granite based mostly on the proportion of quartz and potassic feldspar. At the base of Cerro Uritorco, where the unit is cut by numerous steep east-dipping Cainozoic faults, the granite is fractured with common haematite and fluorite alteration.

Minor dyke rocks

Pegmatite

Several generations of pegmatite dykes intrude basement metamorphics and granitic rocks. The oldest are form small deformed pods, less than a metre wide. These pegmatites are probably the product of partial melting during Cambrian M1 metamorphism (Pampean).

In the Sierra Chica numerous folded muscovite-quartz- K-feldspar pegmatite dykes, up to 10 m wide, are associated with the latest stages of Early Cambrian felsic (tonalitic) magmatism in the region, post-dating the medium-grade Pampean deformation and earlier metaluminous granitic intrusion. These occur particularly along the western margin of the Ascochinga Igneous Complex and throughout the Güiraldes Tonalite and immediately adjacent to the La Falda Metamorphic Complex metamorphics (within two kilometres). The pegmatites are folded and deformed by regional F2 open folds and the S2 foliation (?Famatinian) and are localised, in low-strain zones associated with the folds, indicating syn-tectonic emplacement. K-Ar dating of muscovite from one such pegmatite, from the neck of an F2 boudin of tonalitic orthogneiss, yields a minimum age of 428 Ma (Camacho, 1997)

Aplite

Aplite dykes are common, particularly in the far northeast, where they form late-stage dykes intruding the Ascochinga Igneous Complex.

Lamprophyre

Minor lamprophyre (vogesite) dykes, up to 1 m wide, intrude the Ascochinga Igneous Complex in the Sierra Chica and near Jesús María township. The dykes are poorly exposed and are extensively altered to carbonate, chlorite and epidote. Typically, they have chilled margins and contact rocks are intensely fractured, with closely spaced joints parallel to dyke margins.

The dykes trend northwesterly and northeasterly, parallel to faults and joints developed at the close of the Devonian Achalian deformation. The age of the dykes is not known. Similar dykes in the Sierras Comechingones postdate Early Devonian thrusts and are late Paleozoic to 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/early Carboniferous "Chánica Orogeny" (correlated with the final phase of the Achalian cycle).

2.4. MESOZOIC

Cretaceous sedimentary and minor mafic volcanic rocks are widespread along the eastern and western margins of the Sierra Chica. In the region, these units include the Los Terrones Conglomerate in the north, the Rosario Conglomerate near La Cumbre and the Saldán Formation east of the Sierra Chica. The continental redbed deposits were deposited in Early Cretaceous half-grabens developed adjacent to the Punilla Fault along the western scarp of the Sierra Chica and the La Calera Fault along the eastern margin of the range (Kay and Ramos, 1996). Both half-grabens were inverted with bounding faults reactivated during Cainozoic Andean uplift to form the present-day morphology.

Rosario Conglomerate (Kr, Kb)
Polymictic conglomerates, lithic arenite and nepheline basalt

Remnants of valley-fill *polymictic conglomerates and poorly sorted lithic arenite* (Kr) referred to as the Rosario Conglomerate (Piovana, 1996) form small isolated cappings unconformably resting on metamorphic and granitic basement along the western scarp and summit of the Sierra Chica south of Cerro Uritorco.

Near Estancia El Rosario a *nepheline basalt* flow (Kb), up to 5 m to 35 m thick, is intercalated with the sediments (Gordillo and Lencias, 1967). Piovana (1996) placed the basalt in the "Groupo volcaniclástico de El Pungo". A total rock K-Ar age determination on the basalt yields a Cretaceous age of 119 ± 10 Ma (Gonzalez and Toselli, 1975), placing it contemporaneous with flood basalt generation in the Parana Basin. Trace element and isotopic analyses indicate that the basalt, together with other Cretaceous basalts, in the Sierras de Córdoba, are the product of small percentage melting (<2%) in garnet-bearing OIB-like mantle (Kay and Ramos, 1996). Basalt clasts within the Saldán Formation give a K-Ar total rock age of 100.5 ± 2.8 Ma (Piavano, 1996).

Los Terrones Conglomerate (Kt)

Polymictic conglomerate and feldspathic lithic quartz arenite

Deposits of *polymictic conglomerate* and *feldspathic lithic quartz arenite* north of Capilla del Monte in the Sierra Pajarillo were informally named and described by Massabie (1982) as the Los Terrones Conglomerate. The unit forms smooth rounded hills with dendritic drainage in the far north. Best exposures of the unit are in the vicinity of Los Terrones, north of Cerro Uritorco.

The sediments form remanent continental fan deposits with clasts in the basal conglomerates up to 3 m across. Regular variation in clast size defines a crude stratification of medium to thick beds. The rocks unconformably overlie metamorphic basement forming a gently north-dipping (10°) sequence in the north, and are locally deformed adjacent to reactivated basement faults.

The Cretaceous age for the deposits is inferred by regional correlations with similar continental redbed deposits (Gordillo and Lencinas, 1970; Massabie, 1982).

Saldán Formation (Ks)

Polymictic conglomerate and coarse-grained poorly sorted clastic sediments

Low rounded hills of *polymictic conglomerate* and *coarse-grained poorly sorted clastic sediments* onlapping metamorphic and plutonic basement rocks along the eastern flank of the Sierra Chica and on the plains between the Sierra Chica and Jesús Maria township are mapped as the Saldán Formation. The formation, as mapped, almost certainly contains areas of reworked undifferentiated Cainozoic gravels which could not be readily separated during the mapping program. The formation was deposited as a coalesced fluvial fan, up to 250 m thick, sourced locally from the Sierra Chica (Santa Cruz, 1978). Synsedimentary basaltic volcanism, correlated with the Early Cretaceous "Groupo volcaniclástico de El Pungo", is indicated by a high volcanic component in the upper part of the unit (Piavano, 1996).

2.5. CAINOZOIC

2.5.1. Tertiary to Quaternary

Undifferentiated deposits (Czu)

The most extensive Cainozoic unit is an intercalated sequence of undifferentiated fluvial and aeolian deposits and paleosols which cover a large part of the Pampean region. The upper loess portion of the unit has been mapped in the area east of the Sierra Chica as the ?Upper Pleistocene "Formación General Paz" by Santa Cruz (1978). Strasser and others (1996) correlated similar deposits in the San Luis region with Late Pleistocene and Holocene units in the Buenos Aires Province.

The unit is dominated by pinkish loess which covers all older units forming a mantle or rarely dune fields which cover and preserve pre-existing topographic relief between the main Pampean ranges. Present river courses and associated deposits locally dissect the deposits except in some places adjacent to ranges where active fluvial fan deposits (Qg) are advancing over the loess.

The loess deposits comprise mostly friable illite and silt. Material was derived from both the metamorphic-igneous basement rocks and a volcanic-pyroclastic source (Santa Cruz, 1978).

Fluvial fan deposits (Czg)

Raised fluvial fan deposits of unconsolidated gravels form low wooded dissected hills at the base of many of the main Cainozoic fault scarps and along the eastern flank of the Sierra Chica. These deposits correspond to Massabie's (1982) interpreted Pleistocene"level 1"deposits in the Punilla Valley.

2.5.2. Quaternary

Fluvial fan deposits of unconsolidated bouldery gravels (Qg)

Holocene (Santa Cruz, 1978) to Recent fluvial fan deposits of unconsolidated bouldery gravels interfinger downslope with finer-grained alluvial deposits (Qa). The fan deposits occur along the base of the Punilla Fault scarp on the western flank of the Sierra Chica. Massabie (1982) mapped the deposits as Level II in his subdivision of Quaternary units in the Capilla del Monte area.

Alluvial deposits of clay, sand and gravel (Qa)

Holocene (Santa Cruz, 1978) to Recent alluvial deposits of clay, sand and gravel along active river courses and adjacent terraces have been designated Qa. The unit includes the

Level III Quaternary unit of Massabie (1982) in the Capilla del Monte area. The most extensive deposits are associated with the Ríos Pinto, Santa Sabina and Ascochinga east of the Sierra Chica.

Talus deposits (Qt)

Minor Recent talus deposits of granitic debris, derived from basement rocks, occur on the western slopes of Cerro Uritorco. The steep slope is reverse fault scarp formed during the Cainozoic Andean cycle.

3. TECTONICS

Three major deformation/metamorphic and magmatic events have affected basement rocks: the Early Cambrian Pampean cycle, the Early Ordovician Famatinian cycle and the Devonian Achalian cycle. Faulting and block-tilting occurred during the Mesozoic and later Cainozoic Andean Cycle.

3.1. PAMPEAN CYCLE

Early Cambrian deformation and metamorphism

No original sedimentary structures, such as bedding, are unequivocally recognised in the metamorphic rocks. Regionally, the oldest preserved structure is a medium-grade metamorphic differentiated foliation which is well-preserved in pelitic gneiss of the La Falda Metamorphic Complex and pelitic and carbonate metasediments of the El Manzano Formation. This foliation (S1), is a penetrative gneissic foliation in pelitic gneiss, defined by leucosome lenses and bands and foliated muscovite-biotite-rich bands. In amphibolite and calc-silicate rocks the foliation forms strongly differentiated mineralogical bands with aligned horn-blende. Throughout most of the region the S1 foliation forms the dominant trends on aerial photographs and satellite imagery, trending mostly NNW, and dipping steeply to the east. An exception to this trend is in the centre of the Ascochinga Igneous Complex, near Bajo Los Olmos, where the gneissic foliation in paragneiss bodies is concordant with granitoid boundaries, trending east-west.

Quartzite resistors in the La Falda Metamorphic Complex, exposed in the adjacent sheet area to the west, preserve an earlier differentiated cleavage of spaced biotite-rich folia which are truncated by leucosome veinlets and the differentiated S1 gneissic foliation. This foliation has not been observed in Jesús María.

Sillimanite-garnet assemblages in pelitic gneiss indicate M1 metamorphism was at least upper amphibolite facies and abundant muscovite-pegmatites and leucosome (forming sub-concordant lenses with S1), suggest limited partial melting took place. Estimates of peak metamorphic conditions for the Sierra Chica are mostly about 6 Kb, and 700°C to 800°C (Pérez and others, 1996; Baldo and Casquet, 1996). Uranium-lead dating of zircon rims and monazite grains which grew during the peak metamorphic event (M1) in both the Pichanas and Cruz del Eje Metamorphic Complexes, to the west of the sheet, give an age of about 530 Ma (Camacho and Ireland, 1997), interpreted here as the age of the M1/D1 event of the Pampean Cycle.

3.2. FAMATINIAN CYCLE

Ordovician deformation and metamorphism

Widespread isoclinal folding and thrusting, at lower amphibolite/upper greenschist facies conditions, throughout the region is attributed to the Early Ordovician Famatinian Cycle.

Within metasedimentary gneissic units of the El Manzano Formation and the Ascochinga and La Falda Metamorphic Complexes, an S2 foliation, subparallel to S1, is axial plane to macroscopic and mesoscopic isoclinal F2 folds. Tonalitic bodies within the La Falda Metamorphic Complex which intruded as subconcordant intrusions after S1, are folded with limbs commonly boudinaged.

In areas of penetrative S2 development all planar D1 fabric elements are rotated into parallelism with the S2 foliation with a pronounced mineral lineation (L2) of biotite, muscovite and quartz, which plunges shallowly to the east (~ 100°). This lineation is perpendicular to long axes of boudinaged tonalitic layers, indicating a broadly coaxial deformation. Lower amphibolite/upper greenschist facies metamorphism (M2) is indicated.

Within granitoids of the Ascochinga Igneous Complex a variably developed gneissic foliation, defined by aligned biotite and hornblende, dips moderately to the east. Primary quartz and feldspar grains are deformed with some recrystallised polygonal mosaic development. The foliation becomes a penetrative mylonitic foliation within 500 m of the Carape Fault where it forms shear planes with a steeply pitching mineral elongation lineation. Shear zone fabrics indicate reverse movement with the Ascochinga Igneous Complex thrust over the El Manzano Formation to the west. The moderate easterly dip of the Fault is also reflected by magnetic anomalies along the entire length of the zone.

The age of this deformation is poorly constrained in the Sierra Chica. K-Ar and Rb-Sr dating of muscovite from a pegmatite emplaced syn D2 yields a minimum age of about 428 Ma (Camacho, 1997). The deformation (D2) is interpreted here as part of the Early Ordovician Famatinian Cycle which is dated in the Sierras de San Luis at about 490 Ma (Camacho, 1997).

3.3. ACHALIAN CYCLE

Devonian deformation and metamorphism

Throughout much of the region, particularly in the west, medium-grade D1 and D2 fabric elements are locally rotated into parallelism by a shallow- to moderately- ENE-dipping penetrative D3 shear fabric associated with westerly-directed thrusting. To varying degrees, this deformation affects all basement rocks in the region, including the Early Devonian Capilla del Monte Granite. Zones of high-strain were focussed in two mylonite zones west of the sheet area, (one west of the Sierras San Marcos passing west of La Falda within the western margin of the La Falda Metamorphic Complex and the parts of the Quilpo Formation, and the other, in the north to north-west-trending Guamanes Shear Zone).

In granitoids of the Ascochinga Igneous Complex minor, but ubiquitous, late epidote, sericite and carbonate alteration of plagioclase and marginal alteration of biotite to either chlorite or intergrown muscovite, haematite and epidote are possibly related to Achalian retrogression (M3). Haematite, present in late fractures may also be of this age or associated with younger Mesozoic or Cainozoic faulting.

A complex system of rectilinear brittle subvertical sinistral NW- and dextral NE-trending strike-slip faults, breccia zones, fractures and kink zones (S4) affect all the basement units in the Sierra Chica, crosscutting the S3 foliation where present. Regional faults are rarely exposed, but are prominent on aerial photographs and Landsat images. Some of the faults are also delineated on magnetic images as zones of demagnetisation.

The orientation and conjugate relationship of the WNW- and NE-trending strike-slip faults, breccia zones and fractures indicates a possible continuation of the east-west compressive regime that accompanied S3 and S4 development. This fracture system is developed throughout the Sierras Pampeanas, and in Córdoba and La Ríoja 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 (Camacho, 1997). These faults zones therefore represent the final stage of the Achalian Cycle.

3.4. MESOZOIC FAULTING

The Punilla and La Calera Faults are interpreted to have initiated as Early Cretaceous east-dipping extensional faults (Sanchez and others, 1995) which were active during deposition of the Early Cretaceous continental deposits such as the Los Terrones and Rosario Conglomerates and the Saldán Formation.

The Punilla Fault is well exposed along the dissected western scarp of the Sierra Chica. The fault is not a discrete fault, rather it is a 2 to 3 km wide fault zone comprising brecciated rocks cut by zones of intense shearing. Within the zone, basement rocks, including the Devonian Capilla del Monte Granite, are brecciated and broken into a tectonic melange: pelitic gneiss is converted to chlorite schist and granitic orthogneiss is fractured and sheared with locally intense haematite-chlorite-epidote alteration. Locally, quartz veins cut the shear planes. Shear planes with steeply pitching slickenlines dip steeply to moderately (75°) to the east. This deformation can be attributed to Early Cretaceous deformation (or older) as both the Los Terrones and Rosario Conglomerates are relatively undeformed, unconformably overlie the fault rocks.

3.5. ANDEAN CYCLE

Reverse faulting

The Sierra Chica is an example of a basement tilt block which formed by east-west compression during the Cainozoic Andean uplift (Jordan and Allmendinger, 1986). The range slopes gently to the east and is bounded to the west by an escarpment developed on the moderate to steep east-dipping reverse Punilla Fault, which extends along the full length of the Sierra Chica. The fault is a reactivated Mesozoic structure. Quaternary faulting effects are limited to characteristic haematitic zones of fault gouge up to 5 m wide which dip 30-55 ° to the east, crosscutting older Cretaceous melange and steeper fault fabrics.

Two major north-trending Quaternary faults are also interpreted in the subsurface east of the Sierra Chica. Aeromagnetic patterns indicate a 1 km wide zone of alteration passing immediately west of the Jesús Maria Fault and another in the far northeast near Sarmiento. In both areas, exposed granitoids close to the interpreted faults are extensively haematised and fractured. Minor haematitic gouge zones, faults and fractures are also exposed in granite quarries near Jesús Maria township.

In the Sierras Comechingones to the south, Costa (1996) interpreted the last and most significant movement on similar faults in the region during the Late Pliocene-Pleistocene with some movement continuing during the Quaternary.

4. GEOLOGICAL HISTORY

The Jesús María sheet area forms part of the southern Sierras Pampeanas, comprising basement ranges of early Palaeozoic metamorphic rocks and Palaeozoic granitoids, separated by intermontane Mesozoic and 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 which either accreted or developed on a western convergent margin of the Río Plata craton (e.g. Demange and others, 1993; Escayola and others, 1996, Kraemer and others, 1995, 1996). Recent geochronological studies (e.g. Rapela and others, 1996), together with U-Pb isotopic age determinations, indicate that their are two principal domains in the southern Sierras Pampeanas: an older Cambrian Pampean domain, and a younger Ordovician Famatinian domain to the west, not exposed in the map area. Both domains share a common geological history since early Ordovician times. The boundary between the domains is broadly coincident with a regional change in the gravity on western flank of the Sierras de Córdoba (Miranda and Introcaso, 1996) and is marked by the Río Guzman Shear Zone in San Luis Province. The geological history of the sheet area is summarised in Table 4.1.

4.1. EARLY CAMBRIAN SEDIMENTATION

The oldest rocks in the region form a structurally thick sequence para-gneisses which comprise parts of the La Falda and Ascochinga Complexes. Carbonate-rich metasediments also occur within the complexes and in a major semicontinuous belt designated the El Manzano Formation. These metasediments are interpreted as being deposited on a passive margin, developed during intracontinental rifting and break up of Laurentia from Gondwana in Eocambrian times at about 540 Ma (Dalziel and others 1994) in a tectonic environment similar to that envisaged by Dalla Salda and others (1996). Lithological similarities and comparable ages indicate that the metasediments may be correlatives of the Early Cambrian (Aceñolaza and Toselli, 1981) Puncoviscana Formation in the northern Sierras Pampeanas as postulated by Willner and Miller (1986).

4.2. PAMPEAN CYCLE

Early Cambrian deformation, metamorphism, mafic and felsic intrusion

Following intrusion of rare tholeiitic mafic dykes, the sediments were deformed at mid-crustal levels by a compressive event (D1) and metamorphosed at mostly upper amphibolite facies to form banded gneiss and locally migmatites. Mafic dykes were converted to amphibolite and extensively boudinaged. Muscovite-pegmatites formed subconcordant lenses. Estimates of peak metamorphic conditions for the area are mostly about 6 Kb, and 700°C to 800°C . A penetrative differentiated foliation formed as the last, and possibly second or even third fabric, in a progressive westerly-directed thrusting event. Uranium-lead dating of zircon rims formed during this metamorphic event (M1) in Sierras de Córdoba give an age of ~ 530 Ma (Camacho and Ireland, 1997). In the map area 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 (e.g. 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, granodiorite and granite (La Falda Metamorphic Complex, Ascochinga Igneous Complex, Güiraldes Tonalite). There are no radiometric dates on these intrusions, however, in the Sierra Norte, similar intrusions in a northern extension of the Ascochinga Igneous Complex are dated at ~ 514 Ma.

The granitoids are mostly medium-K calc-alkaline (Pérez and others, 1996) varieties, interpreted to be indicative of a continental magmatic arc setting (Pérez and others, 1996; Lira and others, 1996). Some peraluminous granites are also present: these possibly evolved from high P melting of primitive material that had undergone recent depletion of lithophile element content, with initial $^{87}Sr/^{86}Sr$ ratios indicating some involvement of older crust (Rapela and Pankhurst, 1995).

Table 4.1. Summary of the geological history of the Jesús Maria 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 Stuart-Smith (1997).

Tectonic Cycle	Age (Ma)	Deposition	Deformation	Intrusion
Andean	Cainozoic	Alluvial, aeolian and talus deposits.	Reverse faulting, block tilting	
	Cretaceous	Conglomerates, arenite and basalt	Normal faulting on the Punilla and Calera Faults	Basalt dykes
Achalian	~355		NW and NE conjugate strike-slip faulting	Lamprophyre dykes
	404		Westerly-directed thrusting, mylonitic foliation (S3), open F3 folding, retrogressive greenschist facies	Capilla del Monte Granite
Famatinian	~490		Mylonitic S2 foliation isoclinal F2 folding, thrusting on the Carape Fault. Lower amphibolite/ upper greenschist facies	
Pampean	515		Differentiated S1 foliation, amphibolite facies	Tonalite, granite, granodiorite and minor mafic rocks
	530			
	?540	Pelitic and carbonate sediments of the El Manzano Formation and La Falda and Ascochinga Complexes		

4.3. FAMATINIAN CYCLE

Early Ordovician Deformation and 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 an accretionary wedge and the Pampean domain during a widespread deformational, metamorphic and magmatic event throughout the

Sierras Pampeanas 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). A compressive deformation (D1 in the Famatinian domain, D2 in the Pampean domain), at mostly upper amphibolite facies, was accompanied by the development of kilometre-scale east-dipping ductile shear-zones with, orthogonal westerly-directed thrust movement (e.g. Martino, 1993; Martino and others, 1994). The Ascochinga Igneous Complex was thrust over the El Manzano Formation at this time. In the Sierra Chica and elsewhere in the Pampean domain earlier D1 fabrics were tightly folded with local axial plane crenulation cleavage, subparallel to the higher grade differentiated D1 fabric.

Dalla Salda (1987) and Toselli and others (1992) ascribed this deformation to the D2 domain. Zircons which grew during this event yield an age of about 480 Ma dating the timing of peak metamorphism in the Famatinian Terrane in San Luis (Camacho and Ireland, 1997). Within the Jesús María sheet there is little evidence for the younger extensional deformation or magmatism.

4.4. 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 both the Famatinian (D2) and Pampean domains (D3), and the development of an Early Devonian magmatic arc. The deformation was dominated by orthogonal westerly-directed thrusting and the development of regionally extensive ductile shear zones with intensive greenschist facies retrogressive fabrics. Locally, outside the principal shear zones, such as in the Jesús María area, the metamorphic rocks were open to isoclinally folded with an axial crenulation developed in places. Dalla Salda (1987) defined this deformation as D3, placing it in the "Ciclo Famatiniano".

Peraluminous to slightly peralkaline felsic melts (e.g. Capilla del Monte Granite), generated from partial melting of MgO depleted crustal rocks (Dalla Salda and others, 1995) intruded the metamorphics discontinuously during and after shear zone development. U-Pb zircon dating of these granites in the southern Sierras Pampeanas brackets crystallisation of the felsic magmas and shear zone formation over a 20 Ma period between 404 Ma and 384 Ma. 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 domain.

The final stages of the Achalian cycle were the province-wide development of a complex system of rectilinear brittle-ductile vertical NW- and NE-trending strike-slip faults and fractures. The orientation and conjugate relationship of the fractures indicates a continuation of the east-west compressive regime. Locally, in other areas the structures are associated with vein-type Au±Cu mineralisation, the result of mesothermal activity interpreted to be associated with the waning stages of magmatic arc activity as the centre of magmatic activity migrated westward (Ramos and others, 1986). Muscovite Ar-Ar ages indicate that this stage began about 385 Ma, peaked at 370 Ma and continued until 355 Ma (Camacho and Ireland, 1997). Toselli and others (1996) attribute development of the fracture system to a 355 Ma old “Chánica Orogeny”.

4.5. MESOZOIC SEDIMENTATION AND MAGMATISM

During the Early Cretaceous, extensional faulting, including probable reactivation of the Punilla and La Calera Faults, accompanied local deposition of continental clastics in half grabens. Mafic magmas, generated by partial melting (<2%) of garnet-bearing OIB-like mantle (Kay and Ramos, 1996), formed minor dykes or extruded as basalt flows intercalated with the sediments. Age determinations on the mafic rocks range from 150 Ma to 56 Ma (Linares and González, 1990).

4.6. ANDEAN CYCLE

East-west compression during the Cainozoic Andean uplift resulted in Neogene inversion of the Cretaceous basins (Schmidt, 1993) and block tilting of basement rocks, forming the present day geomorphology which is dominated by north-south oriented ranges (e.g. Sierra Chica) separated by intermontane basins. The ranges are bounded by escarpments developed on moderate to steeply-dipping reverse faults (Jordan and Allmendinger, 1986; Martino and others, 1995; Costa, 1996), many of which show repeated reactivation (e.g. La Punilla Fault). Costa interpreted the last and most significant movement in the region took place during the Late Pliocene-Pleistocene with some movement continuing during the Quaternary.

SECTION2: ECONOMIC GEOLOGY

by Roger G. Skirrow

1. INTRODUCTION

The 3163-13 (Jesús María) sheet area contains few metallic mineral occurrences, with only single occurrences of U and W presently known. However, the region is well endowed in dimension stone including marble from the El Manzano Formation.

In the Geoscientific Mapping of Sierras Pampeanas Cooperative Project the principal metallic deposits in all main mining districts of the map area were investigated in the field, and geological observations were entered into the ARGROC and ARGMIN databases (Skirrow and Trudu, 1997). ARGMIN is a Microsoft Access database that was initially developed jointly by AGSO and the Subsecretaría de Minería in ORACLE, based on OZMIN (Ewers and Ryburn, 1993). Additional geological and resource data from the literature on mineral occurrences have been compiled in ARGMIN. 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 Skirrow, 1986), as well as $^{40}Ar/^{39}Ar$ radiometric age dating (Camacho, 1997). Geographic coordinates were measured by GPS (locational accuracy 50 m), whereas those occurrences not visited in the field were generally located on aerial photographs and their geographic coordinates digitised. The locational accuracy for photo-located occurrences is 200 m. The locations of remaining occurrences are taken from various published sources, which in some cases allow only very approximate geographic coordinates to be estimated (e.g. 3 km for U deposits).

Mineral occurrence data as well as non-metallic mineral and dimension stone occurrences are shown on the 1:100 000 scale metallogenic map accompanying this report. Output data sheets from the ARGMIN database are appended to the report. Details of the geology and grade-tonnage data, where available, for individual metallic mineral occurrences may be found in the database. The 1:250 000 scale Metallogenic Map for the Sierras Septentrionales de Córdoba (Skirrow, 1997) shows the mineral occurrences in relation to 'prospectivity domains' or areas of mineral potential. These domains are defined on the basis of 'metallogenic models' for each mineral deposit style, as discussed by Skirrow (1997X) and which were developed from the observations and interpretations presented in the following sections. For further datasets of mineral potential, the reader is referred to the *Atlas Metalogenético* (1:400 000 scale) for the Sierras Pampeanas mapping project (Skirrow and Johnston, 1997) and project GIS (Butrovski, 1997) in which metallogenetic models for the principal styles of metallic mineralisation are presented as separate coverages.

2. METALLIC MINERAL OCCURRENCES

No significant metallic mineral deposits are known from the Sheet 3163-13 area. A uranium occurrence is described below. No descriptions or accurate locations are available for the W occurrence shown on the 1:750 000 scale map of Ricci (1974).

2.1. URANIUM: CERRO URITORCO - CASA LA PLATA

Lira and others (1993) described a pitchblende (uraninite) occurrence at Casa La Plata, near Cerro Uritorco in the Sierra Chica. The pitchblende occurs in thin quartz veins cutting granitic pegmatite at the margin of the Granito Capilla del Monte, and is associated with fluorite, calcite, pyrite, haematite and 'gummite'. Anomalous quantities of rare earth elements were reported.

3. NON-METALLIC MINERALS AND *ROCAS DE APLICACION*

3.1. LIMESTONE, MARBLE

A large number of deposits of limestone, dolomite and marble are present in the region. Some of the larger worked deposits occur in belts of intensely deformed early Cambrian metacarbonate-amphibolite rocks, including deposits in the El Manzano Formation in the Sierra Chica.

3.2. FLUORITE, CLAY, OCHRE, STEATITE, GARNET AND AMPHIBOLITE

Several worked occurrences of fluorite, clay, ochres, steatite, garnet, amphibolite were shown on the maps of Ricci (1974), Pastore and Methol (1953) and Lucero and Olsacher (1981), and on the 1995 Mapa Geológica de la Provincia de Córdoba (1:500 000 scale).

3.3. MICA, QUARTZ, FELDSPAR

Numerous relatively small pegmatite bodies have been worked for muscovite, quartz and feldspar and occur widely throughout the region (Ricci, 1974).

BIBLIOGRAPHY

ACENOLAZA, F.G., and TOSELLI, A.J., 1976. Consideraciones estratigraficas y tectonicas sobre el Paleozoico inferior del Noroeste Argentino. Memoria, II Congreso Latinoamericano de Geología, 2, 755-764.

ACENOLAZA, F.G., and TOSELLI, A.J., 1981. Geología de Noroeste Argentino. Publicacíon especial Fac. Ci. Nat. UNT, Tucumán, 1287, 212 p

ASTINI, R.A., 1996. Las fases diastroficas del Paleozoico medio en La Precordillera del oeste Argentino - evidencias estratigraficas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 509-526.

BALDO, E., and CASQUET, C., 1996. Garnet zoning in migmatites, and regional metamorphism, in the Sierra Chica de Córdoba (Sierras Pampeanas, Argentina). XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 507.

BUTROVSKI, D., 1997. Geographic Information System (GIS) for the Sierras Pampeanas Mapping Project, Argentina. Australian Geological Survey Organisation, Arc/Info GIS.

CAMACHO, A. and IRELAND, T.R., 1997. U-Pb geochronology, final report. Geoscientific mapping of the Sierras Pampeans, Argentine-Australia Cooperative Project, Australian Geological Survey Organisation, unpublished report.

CAMACHO, A., 1997. ^{40}Ar-^{39}Ar and Rb-Sr geochronology, final report. Geoscientific mapping of the Sierras Pampeans, Argentine-Australia Cooperative Project, Australian Geological Survey Organisation,unpublished report.

CHAPPELL, B.W. and WHITE, A.J., 1974. Two contrasting granite types. Pacific Geology, 8: 173-174.

COSTA, C.H., 1996. Analysis neotectonico en las sierras de San Luis y Comechingones: problemas y methods. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 285-300.

DALLA SALDA, L.H, 1987. Basement tectonics of the southern Pampean ranges, Argentina. Tectonics, 6: 249-260

DALLA SALDA, L.H, LOPEZ DE LUCHI, M., CINGOLANI, C., and VARELA, R., 1996. A Laurentia-Gondwana fit: Lower Paleozoic tectonics and granitoids. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 435-440

DALLA SALDA, L.H., CINGOLANI, C., and VARELA, R., 1992. Early Paleozoic orogenic belt of the Andes in southwestern South america: result of Laurentia-Gondwana collision? Geology, 20, 617-620.

DALLA SALDA, L.H., CINGOLANI, C., VARELA, R., and LOPEZ DE LUCHI, M., 1995. The Famatinian Orogenic Belt in South-western South America: granites and metamorphism: an Appalachian similitude?. IX Congreso Latinoamericano de Geología, Caracas, Resumenes.

DEMANGE, M., BALDO, E.G., and MARTINO, R.D., 1993. Structural evolution of the Sierras de Córdoba (Argentina). Second ISAG, Oxford (UK), 21: 513-516.

ESCAYOLA, M.P., RAME, G.A. and KRAEMER, P.E., 1996. Caracterizacion y significado geotectonico de las fajas ultramaficas de las Sierras Pampeans de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 421-438.

EWERS, G.R. and RYBURN, R.J., 1993. User's guide to the OZMIN mineral deposit database. Australian Geological Survey Organisation, Record 1993/94, 69p.

GONZALE, R.R. and ACENOLAZA, F.G. 1972. La cuenca de deposición neopaleozóica-mesozóica del oeste argentino. Fundación e Instituto Miguel Lillo, Tucamán, Miscelánea, 40: 629-643.

GORDILLO, C.E. and LENCINAS, A., 1970. Geologia de Córdoba. Boletin Asociación Geológica de Córdoba. I (1).

GORDILLO, C.E. y LENCINAS, A.N., 1967. El basalto nefelinico de El Pungo, Córdoba. Academia Nacional de Ciencias, boletin 46(1):110-115. Córdoba.

GORDILLO, C.E., 1974. Las rocas cordieríticas de Orcoyana y Cerro Negro - Soto (Córdoba). Boletin de la Asociación Geológica de Córdoba, volume 2, no 3-4, p 90-100.

GORDILLO, C.E., 1984. Migmatites cordieriticas de la Sierra de Córdoba; condiciones fisicas de la migmatización. Acadamia Nacional de Ciencas; Miscelánea 68, 40p, Córdoba.

JORDAN, T.E. and ALLMENDINGER, R.W. 1986. The Sierras Pampeanas of Argentina: A modern analogue of Rocky Mountain foreland deformation. American Journal of Science, 286: 737-764.

KAY, S.M. and RAMOS, V.A., 1996. El magmatismo Cretacico de Las Sierras de Córdoba y sus implicancias tectonicas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 453-464

KRAEMER, P., ESCAYOLA, M.P. and MARTINO, r.d., 1995. Hipótesis sobre la evolucíon tectónica neoproterozoica de las Sierras Pampeanas de Córdoba (30° 40' - 32° 40'), Argentina. Revista de la Asociacíon Geológica Argentina, 50: 47-59.

KRAEMER, P., ESCAYOLA, M.P. and SFRAGULLA, J., 1996. Dominios tectonicos y mineralizacion en el basamento de las Sierras Pampeanas de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 239-248.

LIRA, R., MILLONE, H.A., KIRSCHBAUM, A.M. and MORENO, R.S., 1996. Granitoides calcoalcalinos de magmatico en la Sierra Norte de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 497.

LIRA, R., SFRAGULLA, J. and VINAS, N.A., 1993. Hallazgo de pitchblenda en el Cerro Uritorco, Sierras Chicas de Córdoba. Unknown publisher - Actas del Congreso Geológico Argentino?, 6 p.

LUCERO, H.N.M. and OLSACHER, J., 1981, Descripción Geológica de la Hoja 19h, Cruz del Eje, Provincia de Córdoba (Escala 1:200 000). Servicio Geológico Nacional, Boletín, 179, 96 p.

LYONS, P. and SKIRROW, R.G., 1996. Whole rock and stable isotope geochemistry - Final Report. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

LYONS, P, SKIRROW, R.G. and STUART-SMITH, P.G. 1997. . Report on Geology and Metallogeny of the Sierras septentrionales de Córdoba, 1:250 000 map sheet, Province of Córdoba. Geoscientific Mapping of the Sierras Pampeanas, Argentina-Australia Cooperative Project, Australian Geological Survey Organisation, unpublished report.

LYONS, P., STUART-SMITH, P.G., SIMS, J.P., PIETERS, P., SKIRROW, R.G. and CAMACHO, A., 1996. Whole Rock Geochemistry Report. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report, June 1996.

MARTINO, R.D., 1993. La faja de deformación “Guamanes”: petrografía, estructura interna y significado tectónico, Sierra Grade de Córdoba. Revista de la Asociación Geológia Argentina, 48 (1): 21-32.

MARTINO, R., KRAEMER, P., ESCAYOLA, M., GIAMBASTIANI, M., and ARNOSIO, M., 1995. Transect de Las Sierras Pampeanas de Córdoba a los 32° S. Revista de la Asociacíon Geológica Argentina, 50: 60-77.

MARTINO, R.D., SIMPSON, C., and LAW, R.D., 1994. Ductile thrusting in Pampean ranges: its relationships with the Ocloyic deformation and tectonic significance.GCP Projects 319/376, Novia Scotia, Abstracts.

MASSABIE, A.C., 1982. Geologia de los Alfrededores de Capilla del Monte y San Marcos, Provincia de Córdoba. Revista de la Asociacíon Geológica Argentina, 37: 153-173.

MICHAUT, L.H., 1986. Consideraciones prelimanares sobre los granitoides del Batolito Compuesto de Río Ceballos - Ascochinga, Republica Argentina. Asociacion Geologica de Córdoba, Boletin VIII: 519-525.

MIRANDA, S. and INTROCASO, A., 1996. Cartas gravimetricas y comportamiento isostatico areal de las Sierras de Córdoba - Rep. Argentina. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 405-417.

MURRA, J.A. and BALDO, E.G., 1996. El granito de Capilla del Monte y su encajonante ígneo-metamórfico, Sierras Pampeanas de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 499-505.

PASTORE, F. and METHOL, E., 1953. Descripcion de la Hoja Geologica 19I, Capilla del Monte. Ministerio Industria Cometcio, Direccion Nacional de Mineria, Boletin 79.

PASTORE, F., 1932. Descripcion de la Hoja Geologica 20I, Córdoba. Ministerio Agricultura, Direccion de Mineria y Geologia, Boletin, 36, 67pp.

PEREZ, M.B., RAPELA, C.W. and BALDO, E.G., 1996. Geología de los granitoides del sector septentrional de la Sierra Chica de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 493-505.

PIOVANA, E.L. 1966. Correlación de la Formación Saldán (Cretácico temprano) con otras secuencias de las Sierras Pampeanas y de las cuencas Chacoparanense y de Paraná. Revista de la Asociación Geológica Argentina, 51: 29-36.

RAMOS, V.A., JORDAN, T.E., ALLMENDINGER, R.W., MPODOZIS, C., KAY, S., CORTES, J.M., and PALMA, M.A., 1986. Paleozoic terranes of the Central Argentine-Chilean Andes. Tectonics, 5: 855-880.

RAPELA, C.W. and PANKHURST, R.J., 1995. The Cambrian plutonism of the Sierras de Córdoba: Pre-Famatinian subduction? and crustal melting. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 491.

RAPELA, C.W., PANKHURST, R.J., BALDO, E., and SAAVEDRA, J., 1995. Cordierites in S-type granites: Restites following low pressure, high degree partial melting of metapelites. The Origin of Granites and Related Rocks, Third Hutton Symposium Abstracts. US Geological Survey Circular 1129.

RAPELA, C.W., SAAVEDRA, J., TOSELLI, A., and PELLITERO, E, 1996. Eventos magmaticos fuertemente peraluminosos en las Sierras Pampeanas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 337-353

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.

RIMAN, E., 1918. Estudio geologico de la Sierra Chica entre Ongamira y Dolores. Acadamia Nacional de Ciences de Córdoba, Boletin 22, 129-199.

SANTA CRUZ, J.N., 1978. Aspectos sedimentologicos de las formaciones aflorantes al este de la Sierra Chica, Provincia de Córdoba, Republica Argentina. Asociación Geológica Argentina, revista, 36: 232-244.

SCHMIDT, C., 1993. Neogene inversion of two Cretaceous basins, Sierras Pampeanas, Argentina. Geological Society of America, 1993 Annual Meeting, Boston, Abstracts, 233.

SIMS, J.P., STUART-SMITH, P.G., LYONS, P., PIETERS, P., SKIRROW, R.G. and CAMACHO, A., 1996. Petrography Report. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report, June 1996.

SKIRROW, R.G. and TRUDU, A., 1997. ARGMIN: a mineral deposit database for the Sierras Pampeanas, Republic of Argentina. Australian Geological Survey Organisation, Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project. Database in Microsoft Access and Oracle.

SKIRROW, R.G. and JOHNSTON, A.I., 1997. Atlas Metalogenético de las Sierras Pampeanas, República Argentina. Australian Geological Survey Organisation, Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project.

STRASSER, E.N., TOGNELLI, G.C., CHIESA, J.O. and PRADO, J.L., 1996. estratigrafia y sedimentologia de los depositos eolicos del pleistoceno tardio y Holoceno en el sector sur de la sierra de San Luis. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas IV: 73-83.

TOSELLI, A.J., DALLA SALDA, L. and CAMINOS, R., 1992. Evolucíon metamórfica del Paleozoic Inferior de Argentina. In J.G. Gutiérrez Marco, J Saavedra and I. Rábano (Eds), Paleozoico Inferior de Ibero-América. Universidad de Extremadura.

TOSELLI, A.J., DURAND, F.R., ROSSI DE TOSELLI, J.N. and SAAVEDRA, J., 1996. Esquema de evolucion geotectonica y magmatica eopaleozoica del Sistema de Famatina y sectores de Sierras Pampeanas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 443-462.

WILLNER, A.P., and MILLER, H., 1986. Structural division and evolution of the lower Paleozoic basement in the NW Argentine Andes. Zentralblat fur Geologie und Paläontologie, I, 1245-1255.

ARGMIN

DATABASE OUTPUT SHEETS