Report on

1:100 000 Scale Geological and Metallogenic Maps
Sheet 3366-21

Province of San Luis

John P. Sims and Roger G. Skirrow

GEOSCIENTIFIC MAPPING OF THE SIERRAS PAMPEANAS ARGENTINE-AUSTRALIAN COOPERATIVE PROJECT

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

1997

CONTENTS

SECTION I: GEOLOGY

By John P. Sims

1. INTRODUCTION

1.1 LOCATION AND ACCESS

The 3366-21 map area forms an east-west transect within San Luis Province; ~46km by 40km between latitude 32°40’-33°20’ S and longitude 64°00’-65°30’ W. The area includes parts of two 1:250 000 scale map sheets: San Luis (3366-III), and Sierras de San Luis y Comechingones.

The main population centre is the city of San Luis and access is via national routes 7, 146 and 147. The area covers the southern end of the Sierras de San Luis and includes the minor population centres of Trapiche, Potrero de los Funes, El Volcan and Villa de la Quebrada, and is traversed provincial routes 3, 9, 18 and 20. The main drainage is via Río Chorillos and Arroyo de los Molles to the south-west, and Río Grande, Río Virorco, Arroyo de Las Aguilas, Arroyo de las Manantiales to the east.

1.2 NATURE OF WORK

The mapping of the Sierras de San Luis 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 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. All geological maps were compiled on either published 1:20 000 scale topographic maps where available, or topographic bases produced at photo-scale from rectified Landsat images controlled by field GPS sites.

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.

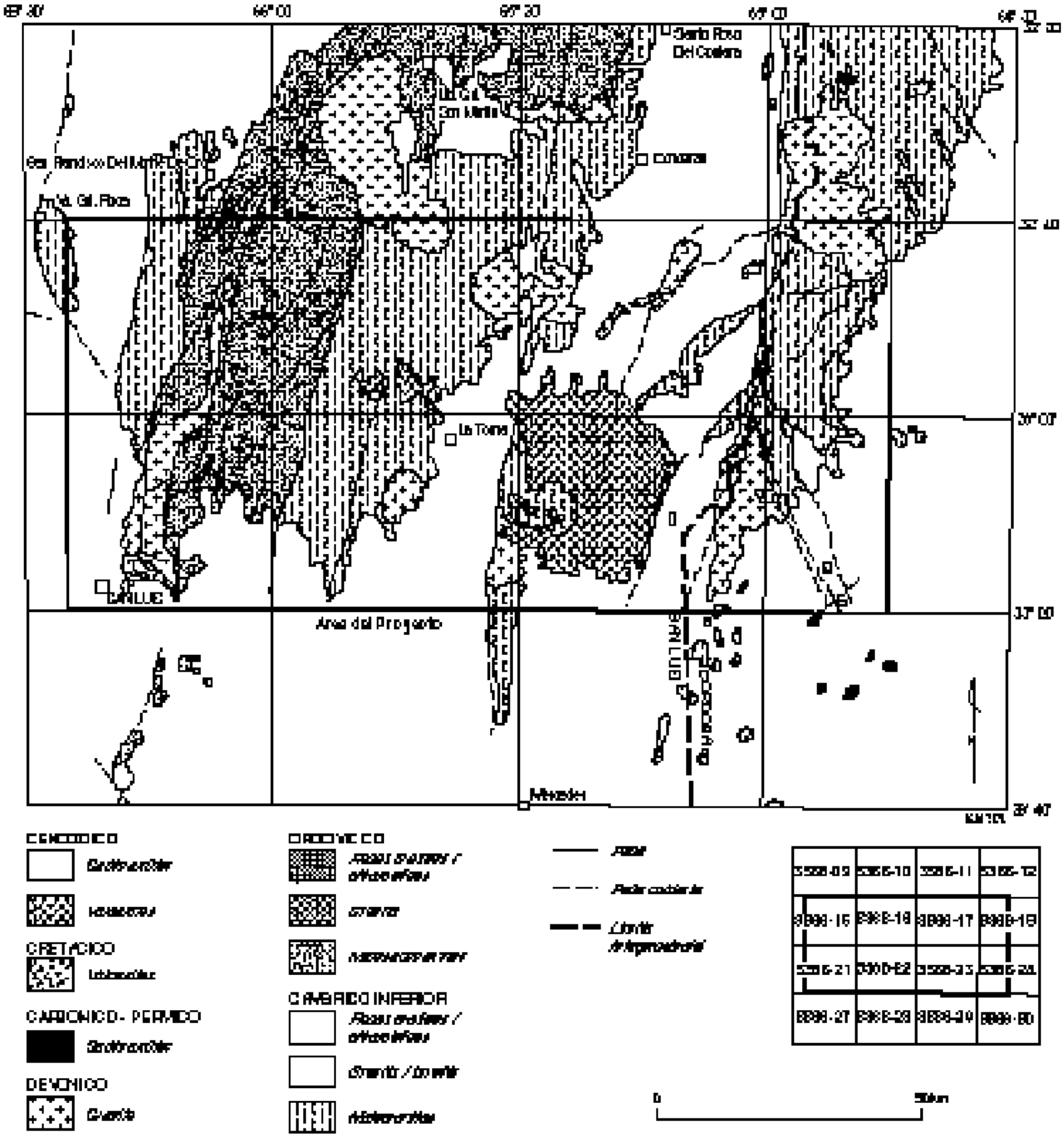

Figure 2. Location of the *Sierras de San Luis y Comechingones* 1:250,000 scale map area in San Luis and Córdoba Provinces with generalised geology. Locations of 1:100,000 scale map areas are indicated.

Topography, including cultural, hydrography and relief data were derived from existing 1:20 000 coverages where available. In areas where existing coverage was not available, culture and hydrography was derived from the rectified Landsat images, and the relief data was derived from the digital terrane model (DTM).

1.3 PREVIOUS INVESTIGATIONS

Previous regional geological mapping was at a scale of 1:200 000, and included investigations by Pastore and Gonzalez (1954) of San Francisco (Hoja 23g), Pastore and Huidobro (1952) of Saladillo (Hoja 24g), and Sosic (1964) of Sierra del Morro (Hoja 24h).

More recent geological investigations have been of greater detail and have concentrated on the stratigraphy (e.g., Prozzi and Ramos, 1988; Ortiz Suárez and others, 1992) , regional structure (e.g., González Bonorino, 1961; Criado Roqué and others, 1981; von Gosen and Prozzi, 1996), the complex igneous intrusive history (e.g., Zardini, 1966; Brogioni and Ribot, 1994; Llambías and others, 1996a, b; Sato and others, 1996; Otamendi and others, 1996; Pinotti and others, 1996), Tertiary volcanism (e.g., Brogioni, 1988; 1990), and extensive studies on the numerous mineral deposits (e.g., Sabalúa and others, 1981; Llambías and Malvicini, 1982).

2. STRATIGRAPHY

2.1 GENERAL RELATIONS

The Sierras Pampeanas are 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. 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.

Rocks of the Cambrian domain in the 3366-21 consist of the Nogoli Metamorphic Complex in the west. The Ordovician domain consists of Cambro-Ordovician rocks of the Pringles Metamorphic Complex and the Early Ordovician San Luis Formation. Several granitic, tonalitic, mafic and ultramafic bodies dominantly intrude the Ordovician domain. The Ordovician domain is intruded by a voluminous Early Devonian granite (Escalerilla Granite) and both the Cambrian and Ordovician domains are partly covered by Cainozoic continental deposits. A summary of the stratigraphy and age relations is shown in Table 1.

Table 1. Summary of the stratigraphy and age relations of the *Sierras de San Luis y Comechingones* (Sims and others, 1997). Age data and discussion of the various tectonic cycles are presented within the text. Some units are not represented on 3366-21.

Tectonic Cycle	Age (Ma)	Deposition	Intrusion
Andean	present	Alluvial, aeolian and talus deposits.	
	1.9–9.5	Volcaniclastics	High-K, calc-alkaline to shoshinitic volcanism
Achalian	355		
	405		I- and S-type granite (e.g. Escalerilla, Renca, Achiras Igneous Complex)
Famatinian	470		Río de Molle monzonite Bemberg suite tonalites Tamboreo granodiorite
		San Luis Formation	
	490		Undifferentiated granitoids Mafic and ultramafic rocks
		Pringles Metamorphic Complex sediments	
Pampean	515		
	530		Undifferentiated granitoids Undifferentiated mafics
		Sediments of: • Nogoli Metamorphic Complex • Conlara Metamorphic Complex • Monte Guazú Metamorphic Complex	?Intrusives

2.2 PALAEOZOIC METAMORPHIC BASEMENT

2.2.1 INTRODUCTION

The metamorphic basement of the 3366-21 consists of three main subdivisions that relate directly to the geological ages of the units. The first subdivision represents basement rocks of at least Cambrian age (Nogoli Metamorphic Complex) that were deformed and metamorphosed during the late Cambrian, Pampean Tectonic-Cycle. The second subdivision represents Cambro-Ordovician rocks of the Pringles Metamorphic Complex that were deposited prior to the onset of collisional tectonics associated with the Famatinian Tectonic Cycle. The third subdivision are the low-grade rocks of the San Luis formation. These rocks were deposited very late in the Famatinian Cycle, probably during a late extensional phase, and display little evidence of the intense effects of that tectonic event. They are, however, intruded by early Ordovician tonalites and granodiorites, and display contact metamorphic aureoles as a result of those intrusions.

2.2.2 CAMBRIAN

Nogoli Metamorphic Complex (€n)

Felsic and mafic orthogneiss, paragneiss, monzonite and quartz-monzonite.

The Nogoli Metamorphic Complex represents the NW region of the Sierras de San Luis. The complex is exposed in 3366-21 in the northwestern escarpment of the Sierras de San Luis in the region of Villa de la Quebrada. The eastern boundary with the Ordovician San Luis Formation is represented by a Tertiary thrust fault that may be a reactivated Devonian structure.

The Nogoli Metamorphic Complex comprises undifferentiated felsic and mafic orthogneiss of probable early Cambrian age, and pelitic gneiss of probable late Neoproterozoic to early Cambrian age, though an older Proterozoic age for the metasediments could not be discounted at this stage. Felsic orthogneiss dominates with subordinate lenses and pods of mafic gneiss (dominantly amphibolite) that preserve complex and discordant, high-grade, structural fabrics. The basement gneiss is intruded by numerous co-magmatic monzonite and quartz-monzonite bodies that occur as both discrete mappable plutons (e.g., Río del

Molle Monzonite; Sims and others, 1997) and as dykes at various scales. The aeromagnetic signature of the complex is relatively low with local anomalies probably related to amphibolite bodies or monzonite intrusions.

The strongly foliated felsic orthogneiss consists dominantly of recrystallised quartz, feldspar and biotite, with muscovite usually developed as a late retrograde phase. In some localities rare K-feldspar porphyroclasts are preserved within the felsic orthogneiss. Subordinate mafic gneiss occurs as layers and boudinaged pods within the felsic orthogneiss and pelitic gneiss, and consists of seriate hornblende, plagioclase, quartz and biotite, with retrograde epidote.

Minor outcrops (and extensive talus of very large boulders up to 15m diameter) consisting predominantly of high-grade pelitic gneiss occur within the Río Amieva to the north of 3366-21. The metapelite consists of a peak metamorphic assemblage of quartz-feldspar-cordierite-sillimanite-biotite with a well developed gneissic fabric, and local spectacular, discordant networks of cordierite bearing leucosome cross-cutting the gneissosity. Additionally, numerous boudinaged pods of amphibolite occur within the gneissic fabric.

The earliest pervasive (concordant) gneissic fabric within the complex trends in a west to northwesterly direction. This early fabric is folded and partially retrogressed through muscovite replacing sillimanite, and is overprinted by subvertical to steeply east-dipping shear zones up to tens of metres in width that trend in a northerly direction. These latter zones, which have recrystallised and retrogressed the early high-grade assemblages, display multiple reactivation with contrasting shear-sense and range in metamorphic grade from amphibolite- to greenschist-facies. Mafic orthogneiss in one of these mylonite zones is characterised by an intense foliation defined by biotite, quartz ribbons and lineated hornblende, with the hornblende partially replaced by biotite, zoisite, clinozoisite and epidote. The latest (low-grade) mylonitic reactivation of these zones, with east-up shear-sense, is correlated with the pervasive Devonian deformation that is associated with the Achalian Tectonic-Cycle.

The Nogoli Metamorphic Complex is clearly distinguished from the Pringles Metamorphic Complex by the significant pre-Ordovician orthogneiss component and lower magnetic response (Hungerford and others, 1996), and probably represents at least an Early Cambrian terrane equivalent to the Conlara and Monte Guazú metamorphic complexes (Sims and others, 1997) further to the east.

2.2.3 CAMBRO-ORDOVICIAN

Pringles Metamorphic Complex (€Opgn, €Ope)

Pelitic and psammitic gneiss and schist, orthogneiss, amphibolite and pegmatite, minor calc-silicate

The Pringles Metamorphic Complex is exposed in the Sierras de San Luis, in three areas between the Conlara Metamorphic Complex in the east and the Nogoli Metamorphic Complex in the west, however, only two of these ocur on 3366-21. The easternmost and largest outcropping region occurs in a continuous north-south belt dissecting the sierras. This belt is fault bound to the east and to the west by the San Luis Formation and partly in the west by the Escalerilla Granite and is well exposed in road cuttings on provincial route 9, north of Trapiche, and within various dissecting rivers and creeks (Río Grande, Arroyo de los Manantiales, Arroyo Las Aguilas, Río Virorco). The Pringles Metamorphic Complex is further exposed to the northwest of the Escalerilla Granite in a small area in contact with the granite in the geographically high portion of the sierras.

The Pringles Metamorphic Complex comprises metasediments of probable late Cambrian - early Ordovician depositional age intruded by early Ordovician mafic and ultramafic rocks of the Las Aguilas Group (*c*. 480 Ma), and by numerous granite and pegmatite bodies. Analysis of zircon separates from felsic orthogneiss (A95JS079e) and monazite separates from pelitic gneiss (A95JS129c) within the Pringles Metamorphic Complex suggest that the rocks reached a metamorphic peak at about the time of emplacement of the Las Aquilas Group, and had cooled to about 600 °C by about 450 Ma (Sims and others, 1997). The peak metamorphic grade in the rocks reached granulite facies, particularly in the region of the Las Aguilas Group intrusions. A close temporal relationship between the age of the Las Aguilas Suite and the peak metamorphism as well as the close spatial relationship, suggests that the ultramafic and mafic rocks may have been the heat source of the metamorphism.

The most abundant rock-types in the Pringles Metamorphic Complex are pelitic and semipelitic gneiss and pelitic and semipelitic schist. The gneiss represents domains where peak (up to granulite-facies) metamorphic assemblages have been preserved, whereas the schist either represents domains of initially lower grade (amphibolite-facies) metamorphism or regions where subsequent deformation has been localised and resulted in a lower grade metamorphic overprint.

The gneiss contains quartz-feldspar-garnet-sillimanite-biotite-magnetite±cordierite ±spinel, is generally massive in outcrop and locally has a high magnetic susceptibility (maximum measured reading of 11371 x 10^{-5} SI). The gneiss generally contains a well developed mineral and compositional layering dipping steeply to the east with a near vertically plunging mineral lineation mostly defined by sillimanite ± biotite. Garnet is typically porphyritic, though locally it forms spectacular symplectic intergrowths with magnetite. Where cordierite is developed it occurs within leucosomes, intergrown with K-feldspar, that cross-cut the compositional layering but are generally flattened in the foliation plane and are elongate parallel to the extension lineation. In addition, cordierite-bearing pegmatites truncate the mineral fabric and are interpreted to represent the melt product of the leucosome forming reactions.

Pods of hornblende-plagioclase±orthopyroxene±clinopyroxene mafic gneiss are abundant within the gneiss and are typically strongly elongated parallel to the mineral lineation. Some mafic pods are partly boudinaged through internal conjugate fracture sets containing veins of plagioclase-orthopyroxene-clinopyroxene, and veins of the same composition as the cordierite-bearing pegmatites.

Within the gneiss, distinct belts of high-grade mylonite occur. These mylonites are of variable composition and locally contain cordierite- and sillimanite-stable assemblages and occasionally are overgrown by mm-scale, euhedral garnets with spiral inclusion trails. The mylonites are particularly well developed on the margins of the ultramafic bodies of the Las Aguilas Suite, which suggests that formation of the mylonites may be in part due to strain localisation along the contact between rheological contrasting rock-types. The mylonites contain a mineral and elongation lineation that is indistinguishable from that in the host gneiss, and generally have well developed shear-sense indicators such as S/C fabrics and winged porphyroclasts that consistently show an east over west displacement sense.

The boundary between gneiss and schist is transitional and is marked by numerous, thin, k-feldspar rich pegmatites that form either thin discontinuous veins or occur as dykes. The schist, which is generally well layered and has a low magnetic susceptibility, consists of a peak metamorphic assemblage of quartz-feldspar-garnet-biotite-sillimanite. A primary compositional layering that consists of alternating pelitic and semi-pelitic units is apparent in many areas of the schist that is not apparent in the higher grade regions of the complex.

Extensive tourmaline-apatite-garnet±beryl-bearing pegmatites occur within the schist and are associated with a number of S-type granite and leucogranite intrusions. These intrusions occur in distinct belts within which, a locally intense, moderate to shallow, dominantly east-dipping shear fabric is developed, with east-down shear sense on a moderately southeast plunging lineation. The shear fabric is mostly defined by muscovite-biotite±chlorite, while the lineation is locally defined by tourmaline. Many of the pegmatites are strongly folded and boudinaged in this shear fabric. Within the metasediments, the earlier, peak foliation was strongly folded and transposed, and texturally the peak sillimanite is largely replaced by coarse poikolitic muscovite+quartz, and fine folia of muscovite. In places, late radiating needles of tourmaline and coarse, unoriented porphyroblasts of muscovite are grown on the secondary foliation plane.

Metre scale, elongate and zoned calc-silicate pods occur within both the gneiss and schist. An example of one of these pods from Arroyo Los Manantiales consists of an outer diopside-anorthite bearing rim with a core rich in calcite, garnet and diopside. These pods possibly represent boudins of originally thin and continuous, interlayered carbonate units, though the present lateral extent cannot be determined.

Orthogneiss comprises a relative minor component of the Complex, is extensively recrystallised and contains quartz-feldspar-garnet±biotite. Garnet is subhedral and poikiloblastic and contains abundant granular inclusions of well-rounded quartz and minor plagioclase.

2.2.4 ORDOVICIAN

San Luis Formation (Osl, Osls, Oslc)

Phyllite, schist, arenite, slate and metaconglomerate

The San Luis Formation (Prozzi and Ramos 1988) occurs in two elongate NNE trending belts in the Sierras de San Luis. The eastern belt is les than 5 km wide and bound to the east by the Río Guzman Shear Zone and to the west by Embalse La Florida and Cerros

Largos (Sims and others, 1997). The southern most portion of this belt is on exposed on 3366-21 before it passes under shallow cover to the south. The western belt is no more than 3 km wide and extends discontinuosly southwards on both the eastern and western margins of Escalerilla Granite. The San Luis Formation is well exposed in Río Quinto below Embalse La Florida, and in both Río Grande and Arroyo de los Manantiales adjacent to Escalerilla Granite.

The age of the San Luis Formation (SLF) is tightly controlled by structural and stratigraphic constraints. The SLF unconformably overlies high-grade basement rocks of the Pringles Metamorphic Complex (metamorphosed at ~480 Ma) and is unaffected by the intense tectonism that has affected those rocks. However, the formation is intruded by the Tamboreo Granodiorite (472 ± 5 Ma), the Bemberg Suite tonalites (471 ± 5 Ma) and by a suite of aplitic to rhyolitic dykes that also cross-cut the Tamboreo Granodiorite (Sims and others, 1997). The contact of the SLF with the Pringles Metamorphic Complex was strongly sheared during the Devonian, with kyanite, staurolite and garnet bearing assemblages and minor quartz-feldspar-muscovite-kyanite-staurolite pegmatites locally developed within the SLF near the contacts. Ar-Ar isotopic analysis on muscovite from one of these pegmatites produced an age of ~365 Ma (Camacho, 1997).

The majority of the SLF consists of medium- to thinly-bedded quartz arenite and phyllite in varying proportion, and include areas dominated by either lithology. Sedimentary structures, such as graded bedding, cross-bedding, channel and flame structures, are common in areas where there is a higher proportion of coarser grained beds. Most rock-types are quartz-rich, and significant carbonate occurs in the matrix of some coarser grained arenites.

Two main deformations affected the SLF during the Devonian compressional cycle. The first of these deformations resulted in tight to isoclinal, upright to inclined folds with a well-developed, axial planar, slaty cleavage in most rock-types. The second deformation resulted in the development of discrete shear zones, separated by domains of open refolding with a corresponding crenulation cleavage. Additionally, a very early foliation is also preserved in fine grained rocks in some areas. The regional metamorphic grade within the SLF is typically lower greenschist and the rocks are generally fine grained. In places though, a more schistose and coarser grained fabric is developed, which probably reflects slight variations in the metamorphic grade, during the Devonian compressional cycle. Local high-temperature metamorphic aureoles are also developed around Ordovician, granodioritic to tonalitic intrusives. The magnetic signature of the San Luis formation is generally low, however, local high magnetic responses are developed in the region of magnetite-bearing Devonian mylonites such as the Río Guzman Shear Zone.

Where axial planes of the two main Devonian deformation phases are sub-parallel and occur in transposed fine-grained rocks, slate is developed. The slate is dark-grey to green and consists predominantly of thinly bedded phyllites with minor thin quartzites. The phyllite consists predominantly of quartz, chlorite and sericite with minor organic carbon (Prozzi and Ramos, 1988) and contain secondary euhedral crystals of calcite and pyrite. The thin quartzites consist predominantly of quartz, chlorite and minor muscovite with abundant secondary euhedral calcite and minor epidote. Both rock-types are cross-cut by thin veins of quartz±pyrite. The slate has been extensively quarried for building stone. Additionally, a distinctive, poorly-sorted, polymictic, conglomerate unit, named the Metaconglomerado Cañada Honda by Ortiz Suárez and others (1992), occurs within the SLF, but is not exposed in 3366-21.

2.2.5 DEVONIAN

Río Guzman Shear Zone (Dzmi)

The Río Guzman Shear Zone is a linear north-northeast trending, high-strain zone, traversing the Sierras de San Luis from the Las Chacras batholith in the north, to near Saladillo in the south (Sims and others, 1997). The zone, which is up to 3 km wide, is not exposed on 3366-21, however, it is a major lineament on aeromagnetic imagery that can be traced on 3366-21, beneath a thin cover of Cainozoic sediments. The shear zone, named after the Río Guzman, which follows the shear zone for several kilometres, has not previously been described.

Where the shear zone is exposed, it consists predominantly of steeply east-dipping mylonite that separates the high-grade, Cambrian Conlara Metamorphic Complex (Sims and others, 1997) from the low-grade, Ordovician San Luis Formation and is largely contained within the low-grade rocks. The dominant assemblage in the mylonite consists of quartz-chlorite-sericite±magnetite with a variably developed subvertical stretching and mineral lineation. Relict (retrogressed) kyanite? with staurolite and garnet, within Conlara Metamorphic Complex rocks on the eastern margin of the zone, near Cerros Largos, however, suggests the shear zone may have initiated at higher pressures and have a long-lived history. Shear-sense indicators in the form of S-C fabrics and assymetric extensional shear bands are well developed and give east up displacement. The similarities of the kinematic indicators and metamorphic grade suggests a close temporal relationship with the Las Lajas Shear Zone in the Sierra de Comechingones.

Ar-Ar data from sericite in the mylonitic fabric, indicates a growth age between 360 and 350 Ma (Camacho, 1997), which therefore constrains the minimum age of the greenschist-facies shearing. Additionally, the shear zone has been intruded by a number of undeformed lamprophyre dykes, and has been partly reactivated as an east dipping thrust during the presently active, Tertiary Andean compression.

2.3 PALAEOZOIC IGNEOUS ROCKS

2.3.1 ORDOVICIAN INTRUSIVES

Las Aguilas Group (Ola)

Dunite, pyroxenite, hornblendite, amphibolite.

Mafic, ultramafic rocks and amphibolite are exposed in a series of discrete elongate bodies up to 3.5 km in outcrop length and up to 500 metres in outcrop width, in two NNE-SSW trending belts, within the Pringles Metamorphic Complex. Mappable ultramafic and mafic units appear to be restricted to a number of intrusions within a belt approximately 5 km wide and approximately 50 km long, to the west of Trapiche, within a region of granulite-facies gneiss, and to a small body just west of Escalerilla granite. Although the ultramafic rocks have a high magnetic reponse, individual bodies within the main belt are not readily distinguished in the aeromagnetics due to the high magnetic response of the enclosing pelitic gneiss. Additionally, numerous metre- to 100 metre-scale, moderately to highly magnetic, amphibolite bodies, representing either differentiated or metamorphosed equivalents of the ultramafic rocks, also occur within the Pringles Metamorphic Complex. These bodies are apparent in the aeromagnetics, particularly away from the region of granulite-facies gneiss, however, due to the small scale or lack of exposure they are not generally differentiated from the Pringles Metamorphic Complex.

The mafic and ultramafic rocks intruded into the Pringles Metamorphic Complex and are spatially and texturally associated with granulite-facies rocks. The margins of the larger bodies, and many of the smaller bodies, are extensively recrystallised with high-grade hornblende-pyroxene-bearing metamorphic assemblages. The recrystallised metabasic rocks are extensively boudinaged and contain a foliation parallel to that in the enclosing pelitic gneiss. Conversely, the cores of a number of the larger mafic bodies preserve relict igneous textures. For example, at Virorco, subhorizontal igneous layering is preserved while at Las Aguilas sub-vertical contacts occur between various intrusive phases. Furthermore, it is apparent that individual bodies are strongly elongate parallel to the stretching lineation in the enclosing gneiss. The implication being that the mafic, ultramafic and amphibolite rocks intruded synchronously with regional deformation.

The age of the Las Aguilas Suite has been constrained by U/Pb dating of zircon seperates from a felsic segregation in the ultramafic rocks at Las Aguilas. The zircons from this late crystallising phase provide an Early Ordovician age of 478 ± 6 Ma (Camacho and Ireland, 1997). Zircons from a spatially associated felsic orthogneiss at Las Aguilas produced a similar age of 484 ± 7 Ma (Camacho and Ireland, 1997).

The mafic and ultramafic rocks are composed of dunite, pyroxenite and hornblendite. Orthopyroxene is typically the most abundant primary mineral phase with subordinate olivine, plagioclase, clinopyroxene, spinel (chromite) and sulphide phases (pyrrhotite, pentlandite and chalcopyrite). Olivine is partially altered to serpentine, clinopyroxene is extensively replaced by clinoamphibole, and phlogopite is locally extensively developed associated with late deformation surfaces. Secondary sulphides include marcasite, covellite and pyrite.

The numerous bodies of amphibolite consist dominantly of hornblende and plagioclase with or without orthopyroxene and contain minor quartz and accessory phases (apatite, sphene, ilmenite and magnetite). Primary hornblende is variably replaced by biotite and secondary hornblende replaces orthopyroxene. Other secondary phases include epidote, zoisite, clinozoisite and calcite.

Undifferentiated granitoids and pegmatite (Ogu, Opeg)

S-type leucogranite, granite, granodiorite, tonalite and pegmatite

Includes a distinctive suite of S-type granite, leucogranite and pegmatite that occur in an elongate NNE trending belt that passes through Embalse La Florida to the east of Trapiche. This group of rocks, which has previously been described as "granitoides sin-cinemáticos" by Ortiz Suárez and others (1992) and Llambías and others (1996a), is well exposed from Embalse La Florida through Paso del Rey and within Río Grande east of Siete Cajoles.

Structural constraints on the "granitoides sin-cinemáticos" suggest that the granites and pegmatites intruded a high-grade (amphibolite facies) basement. Previous geochronology by Linares (1959) and Llambías and others (1991) indicates that the pegmatites associated with these rocks were emplaced prior to 460 Ma.

The undifferentiated granitoids comprise various phases of leucogranite, granite granodiorite and pegmatite. The granite is typically leucocratic and equigranular, containing quartz-feldspar-biotite-muscovite±garnet. The associated pegmatites are extremely coarse grained, feldspar-quartz-muscovite-tourmaline-garnet-apatite bearing varieties that are typically compositionally zoned.

The "granitoides sin-cinemáticos" are spatially associated with zones of extensional deformation developed late in the Famatinian tectonic cycle. They are spatially associated with pervasive retrogression of the high-grade assemblages within the Pringles Metamorphic Complex and development of a muscovite-tourmaline-bearing assemblages at the expense of sillimanite-biotite-bearing assemblages. Complex interference folds defined by pegmatites of this suite suggests multiple deformation episodes. Llambías and others (1996) have estimated that the initial deformation within the granites developed under amphibolite-facies conditions, whilst open refolding is consistent with the initial upright folding of the San Luis formation under greenshist-facies conditions.

Tamboreo Granodiorite (Ogdt)

The Tamboreo Granodiorite forms a slightly elevated plateau ~3 km wide by ~6km long, called Pampa del Tamboreo, which is ~5km to the northeast of Embalse La Florida. Only the westernmost margin of this pluton occurs on 3366-21. Detailed studies of the pluton have been carried out by Zardini (1966) and Sato and others (1996). These previous studies referred to this pluton as the Tamboreo Tonalite.

The granodiorite intrudes the San Luis Formation and has a distinct metamorphic aureole on the eastern margin. The western margin, however, is strongly sheared and in contact with schist of the Pringles Metamorphic Complex. The granodiorite is also intruded by north-south trending aplitic to rhyolitic dykes (Sims and others, 1997). U/Pb geochronology of zircon separates from the granodiorite has produced an early Ordovician age of 470 ± 5 Ma (Camacho and Ireland, 1997).

The granodiorite is grey to pink in outcrop, and contains a low proportion of mafic xenoliths, which are elongate parallel to a locally well-developed foliation (Sato and others, 1996) defined by biotite. K-feldspar proportions range from 1.5% (Sato and others, 1996) to 25% (Sims and others, 1996), which suggests that there is either a strong compositional zonation within the pluton or multiple phases with a range of compositions. Biotite (up to 25%) is the main mafic mineral along with minor epidote. Minor phases include calcite, chlorite, titanite, apatite, allanite and zircon. Recrystallised feldspars and secondary phases including zoisite and muscovite, suggests that deformation of the pluton occurred under upper-greenschist facies metamorphic conditions. The maximum recorded magnetic susceptibility was 25 x 10^{-5} SI. The composition and age of the pluton suggest it is closely related to the Bemberg Suite tonalites (Sims and others, 1997).

2.3.2 DEVONIAN INTRUSIVES

Escalerilla Granite (Dge)

The Escalerilla granite is a large elongate granite with positive relief that forms the main range of the Sierras de San Luis. The granite varies from less than 1 km, to around 8 km in width along an outcrop length of approximately 55 km. The granite is well exposed along the entire length of outcrop, including the southern half of the main western escarpment of the Sierras de San Luis, from near Villa de la Quebrada to the city of San Luis. The northernmost extent of the granite is exposed at Carolina (Sims and others, 1997). Numerous roads, rios and arroyos cross the granite along its entire length.

The granite intrudes basement rocks of the Pringles Metamorphic Complex and the San Luis Formation as well as the Las Verbanas tonalite of the Bemberg Suite (Sims and others, 1997), and contains xenoliths and rafts of all three rock-types. The granite truncates the main structural fabric within the Pringles Metamorphic Complex and is cross-cut by numerous veins and dykes of pegmatite and granite. U/Pb zircon geochronology of zircon separates indicates the Escalerilla granite crystallised at 403 ± 6 Ma (Camacho and Ireland, 1997).

The granite is grey to pink, strongly jointed, and contains up to 30% porphyritic K-feldspar and 25% plagioclase. Biotite comprises up to 10% and muscovite up to 5% of the total rock and accesory phases include sphene, epidote, apatite, clinozoisite and ilmenite. The pluton is non-magnetic.

Quartz (<30%) and biotite are extensively recrystallised and define a mylonitic foliation that is associated with a least two different styles of deformation. The dominant and pervasive fabric is steeply east dipping with a steeply plunging mineral lineation defined by biotite and muscovite with a shear-sense of east over west. K-feldspar porphyroclasts are mechanically rotated in the foliation and are weakly aligned with the lineation. The sub-ordinate mylonitic foliation is generally north trending and is strongly partitioned within the granite, it is sub-vertical in orientation with a sub-horizontal mineral lineation defined by biotite. K-feldspar is partially recrystallised within these shear zones. Various shear-sense indicators show a sinistral displacement sense.

2.3.3 MINOR DYKE ROCKS

Pegmatite (peg)

Numerous pegmatite dykes intrude the basement of *Sierras de San Luis y Comechingones*. There are essentially four mainsubdivisions:

1. Pegmatites emplaced during the M1 metamorphic peak in the Middle Cambrian, at around 530-515 Ma. These are restricted to within the Nogoli Metamorphic Complex on 3366-21.

2. Pegmatites emplaced during the M2 metamorphic peak in the early Ordovician at around 480 Ma. These are largely restricted to within the Pringles Metamorphic Complex.

3. Pegmatites emplaced post-M2 in the mid Ordovician prior to ~460Ma, and associated with the undifferentiated Ordovician granitoids.

4. Pegmatites emplaced during the Devonian,and associated with the extensive granite bodies.

Aplite

A group of thin aplite dykes that are wholly contained within the San Luis Formation and intrusives within those rocks, occur in the Sierras de San Luis. These dykes are up to 5 km in length and no more than 3 m in width. They cross-cut the Tamboreo Granodiorite, and are folded and recrystallised. A minimum age for for the dykes is provided by Devonian ages for the deformation of the San Luis formation. The dykes consist of medium-grained phenocrysts of quartz, feldspar, garnet and muscovite, in a fine grained recrystallised matrix, with minor secondary zoisite. Limited geochemistry from Sato and others (1996) indicates that the dykes are granitic in composition. Brodtkorb and others (1984) have interpreted some of these dykes, that occur within the San Luis Formation as metavolcanics.

Lamprophyre

A number of thin lamprophyre (minette) dykes have also been observed within and adjacent to the Río Guzman Shear Zone in the Sierras de San Luis. These dykes are no more than 1 m in width and consist almost entirely of medium-grained biotite. Within the shear zone, the dykes have intruded parallel to the mylonitic foliation but are not deformed.

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

Unconsolidated cover (Czu, Czg, Czc, Czd)
loess, alluvial deposits, fans, gravels, caliche,channel deposits etc.

Unconsolidated alluvial, colluvial and aeolian deposits, as well as palaeosols, overly the basement rocks in Sierras de San Luis y Comechingones and are interspersed with some of the volcaniclastic deposits. The most extensive Cainozoic unit (labelled Czu) is an intercalted sequence of undifferentiated Tertiary to Quaternary fluvial and aeolian deposits and paleosols that cover a large part of the Pampean region. In areas of low lying relief, these deposits cover all older units and forms a mantle or rarely dune fields between the main Pampean ranges. The undifferentiated Cainoizoic deposits comprise 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.

At the southern end of the Sierras de San Luis, unconsolidated sediments (labelled Czd) preserve evidence of Tertiary basin formation in the region of Potrero de los Funes and San Luis. The sediments consist of poorly sorted, sand and mud dominated beds with a distinctive red colouration. The deposits range from fine-sand to cobbles in grainsize. The unit is unconformably overlain by Cainozoic conglomerates, and both units are dissected by Quaternary alluvial systems.

Raised fluvial and colluvial fan deposits of unconsolidated gravels (labelled Czg) form low, wooded, dissected hills at the base of many of the main Cainozoic fault scarps. The most extensive of these occur along the western scarp of the Sierras de San Luis. These deposits are correlated with similar Pleistocene (Quaternary level 1 subdivision of Massabie, 1982) deposits in the Capilla del Monte area of Córdoba. Increased erosion and exposure of Miocene-Pliocene volcanic plugs from east to west places a lower age constraint on the earliest uplift and hence the maximum age of the fans at mid-Pliocene.

2.5 QUATERNARY

Unconsolidated deposits (Qa, Qg, Qs, Qt)
active alluvial deposits, fans, gravels, talus.

Holocene (Santa Cruz, 1978) to Recent alluvial deposits of clay, sand and gravel along active river courses and adjacent terraces and overbank deposits (labelled Qa) dissect the undifferentiated Cainoizoic units**.** The most extensive of these deposits are associated with the Río Rosario in the south, several rivers draining east from the Sierra Comechingones and west from the Sierras de San Luis, and are also common in numerous minor drainages within the Sierras de San Luis. Bodies of fluvial channel deposits of mainly sand and minor gravel within the presently active channels (labelled Qs) are best developed within the Río Rosario. Active fan deposits (labelled Qg) occur along the base of the fault scarps bordering the Sierra de Comechingones and San Luis.

3. TECTONICS

Three major deformation, metamorphic and magmatic events have affected the basement rocks of *Sierras de San Luis y Comechingones* (Table 1). Rocks of the Monte Guazú, Conlara and Nogoli metamorphic complexes preserve evidence of the earliest event, while the latter two are present within the rocks of the Pringles Metamorphic Complex. The San Luis Formation only shows effects of the latest event. The three tectonic events are termed here the (Early Cambrian) Pampean Cycle, the (early Ordovician) Famatinian Cycle, and the (Devonian) Achalian Cycle. All regions were 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 de San Luis y Comechingones* is a medium- to high-grade metamorphic differentiated foliation which is well-preserved in pelitic gneiss and amphibolite of the Monte Guazú, Conlara and Nogoli metamorphic 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 calcsilicate rocks the foliation forms strongly differentiated mineralogical bands with aligned hornblende. Throughout most of the Monte Guazú Metamorphic Complex the S1 foliation, trends NNW and dips ~45° to the east. The trend of the S1 foliation in the Conlara and Nogoli metamorphic complexes is generally similar, however, the dip of the foliation is more variable due to locally intense reworking during subsequent events. No kinematic indicators where observed.

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 of the Monte Guazú

Metamorphic Complex in the Sierra de Comechingones range from 6.1 to 9.5 Kb, at 700 to 800 °C (Cordillo, 1984; Martino and others, 1994; Cerredo, 1996). No *P–T* estimates exist for the Conlara or Nogoli metamorphic complexes, however, peak metamorphic assemblages in the Nogoli Metamorphic Complex of cordierite-garnet-sillimanite in pelitic rocks, and an apparent scarcity of orthopyroxene in metamafic rocks, suggests pressures of $<\sim7$ Kbars at temperatures of no more than ~750°C (e.g. Grant, 1985; Spear, 1981, 1993).

No isotopic data exist from *Sierras de San Luis y Comechingones* to constrain the age of the Pampean Cycle. However, uranium-lead dating of zircon and monazite from Córdoba (*Sierras de Septentrionales*), which grew during M1 (Lyons and Stuart-Smith, 1997), give an age of ~530Ma (Camacho and Ireland, 1997). Late Pampean granites in Córdoba give ages 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

Formation of a basin, in which the sedimentary protolith to the Pringles Metamorphic Complex was deposited, possibly marks the initiation of a subduction complex to the west of the Sierras de San Luis in the late Cambrian. Numerous intrusives within the La Rioja area that were emplaced around 490-480 Ma (Camacho and Ireland, 1997) probably represent the core of the associated volcanic arc (Pieters and others, 1997). Correlatives of these intrusives within *Sierras de San Luis y Comechingones*, are represented by monzonites and quartz-monzonites (e.g., the Río del Molle Monzonite) emplaced into the Nogoli Metamorphic Complex. The back-arc basin had closed, however, by the early Ordovician, when the Cambro-Ordovician rocks were strongly deformed and intruded by syn-kinematic mafic and ultramafic rocks of the Las Aguilas Group (LAG) at ~480 Ma (Camacho and Ireland, 1997).

Compressional phase

The peak metamorphic assemblages in the Pringles Metamorphic Complex, which formed under granulite facies conditions during the Famatinian Cycle, are spatially located in an elongate belt around the LAG. The pelitic rocks contain a gneissic fabric defined by sillimanite and biotite (S1 in the Pringles Metamorphic Complex but regional S2), with lenses and pods of cordierite- and garnet-bearing leucosomes. The gneissic layering trends N-NNE and dips mostly steeply to the east, and sillimanite and biotite laths define a steeply plunging mineral lineation. A number of discrete mylonite zones are formed within the complex, these are generally less than 20-30 m wide and parallel the gneissic layering. High-grade assemblages involving sillimanite and locally cordierite in the mylonites and a stretching lineation parallel to that in the gneiss suggest they formed synchronously. The mylonites are particularly well developed along the margins of the ultramafic bodies. Shear sense indicators both in the gneissic layering and in the mylonites and give an east-up displacement sense.

In gneiss and schist of the Conlara Metamorphic Complex a schistosity parallel to S1 forms the main penetrative structure. All S1 fabrics are 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.

Extensional phase

By ~470 Ma the compressional regime had ceased and the terrane was in extension, resulting in deposition of the San Luis Formation (SLF). This was followed subsequently by intrusion of the Tamboreo Granodiorite and tonalites of the Bemberg Suite, which produced metamorphic aureoles in the cover rocks.

The extensional structures developed under greenschist-facies conditions, and deformation was partitioned into domains of shearing with a shallow to steep, east to southeasterly dipping lineation and domains of open to tight folding of the older structural surfaces in the basement rocks. Shear fabrics defined by muscovite ± biotite predominate, with a lineation locally defined by tourmaline. Shear sense indicators give an east-down displacement sense. Numerous pegmatites and (fractionated) granites intruded synchronously with the deformation and show varying degress of folding and dynamic recrystallisation. A U-Pb uraninite age of ~460 Ma has been derived from one of these pegmatites (Linares, 1959).

3.3 ACHALIAN CYCLE: DEVONIAN DEFORMATION AND RETROGRESSION

Throughout much of the region, the medium- to high-grade Pampean (D1) and Famatinian (D2) fabric elements are mostly rotated into parallelism by a shallowly- to moderately-dipping, penetrative shear fabric associated with a prolonged collisional episode, termed the Achalian Cycle (Sims and others, 1997). This episode is marked by the development of mylonite in high-strain zones and pervasive, retrogressive greenschist-facies metamorphism and the emplacement of voluminous granite plutons. To varying degrees, the deformation affects all basement rocks, and is probably the the most significant single tectonic episode in the region.

Deformation in the Achalian Cycle involved repeated partitioning of strain between zones of thrusting and zones of strike slip displacement, with repeated overprinting relationships. Domains between shearing were folded and refolded; in some places producing basin and dome interference folds. Strain was focussed in a number of major mylonite zones, in particular, in the northwest-trending Las Lajas Shear Zone, which truncates the Conlara Metamorphic Complex, north of Achiras; and in the north-northeast trending Río Guzman Shear Zone, which separates the Conlara Metamorphic Complex from the San Luis Formation. Additionally, a number of significant mylonite zones developed, including one along the eastern flank of the Sierra de Comechingones, passing through Las Albahacas, and a complex zone that follows the eastern contact of the Escalerilla Granite in the Sierras de San Luis. These deformations have been previously incorporated within the Famatinian Cycle (e.g. von Gosen and Prozzi, 1996)

At least 4 distinct styles of deformation are recognised within the Achalian Cycle (Sims and others, 1997). These styles are in part an effect of the partitioning of strain but also an effect of changing stress or metamorphic conditions in the terrane through the tectonic cycle.

1. Pervasive mylonitic foliation and tight to isoclinal folding

The earliest structural element is a pervasive mylonitic foliation associated with thrusting under upper greenschist-facies conditions. Interference with flat-lying folds in both the Pringles and Conlara metamorphic complexes produced open basin and dome fold-interference patterns. In the early Ordovician San Luis Formation, tight to isoclinal folds are developed in bedding with an axial planar slaty cleavage (S1 in the SLF but regional S3) developed between major shear zones. A maximum age for this early fabric forming event is provided by a 403 ± 6 Ma age (U/Pb zircon; Camacho and Ireland, 1997) for the Escalerilla granite which is affected by the early tectonism. Kinematic indicators including asymmetric mantled porphyroclasts and S-C fabrics all indicate westward-directed thrusting.

2. Ductile strike-slip shearing

Discrete sinistral shear-zones up to 50m wide are developed in a number of areas within the Sierras de San Luis. The shear zones contain a mylonitic fabric with a sub-horizontal mineral and elongation lineation and well developed shear sense indicators. Argon-argon dating (Camacho, 1997) suggests that a change in the regional stress field corresponding to development of ductile strike-slip shearing may have occurred in the Middle Devonian (Sims and others, 1997).

3. *Thrusting at low-grade in discrete shear zones with contemporaeous folding and crenulation of the earlier mylonitic fabric*

Overprinting the strike-slip shear-zones are a number of major low-grade shear-zones that traverse both the Sierras de San Luis (Río Guzman Shear Zone) and the Sierras de Comechingones (Las Lajas Shear Zone and Las Albahacas Shear Zone). These shear zones are up to several kilometres in width, and contain greenschist-facies mineral fabrics that show east-up shear-sense on an easterly plunging lineation, parallel to the early L3 fabric. A regional crenulation cleavage associated with north-south trending open folding is considered to be have developed contemporaneously between the main shear-zones.

4. Brittle-ductile strike-slip faulting typically in conjugate sets trending NW and SW

A complex system of rectilinear brittle vertical WNW- and ENE-trending strike-slip faults, breccia zones and fractures (von Gosen and Prozzi, 1996) affect all the basement units in the Sierras de San Luis and the Sierra de Comechingones, in places displacing the S3 mylonitic foliations and related 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. Within the Sierras de San Luis, where exposed, these faults typically consist of narrow zones (<1 m wide) of brittle-ductile mylonite and minor ultramylonite. Fault mineral assemblages include quartz, sericite, epidote, hematite, goethite and chlorite.

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 and S4 development. This fracture system is developed throughout the Sierras Pampeanas and in Córdoba and La Rioja Provinces. Ar-Ar ages of hydrothermal white micas in the fault zones, in places associated with Au mineralised quartz veins, indicate that this stage began about 385 Ma, peaked at 370 Ma and continued until 355 Ma (Skirrow, 1997b, c).

3.4 ANDEAN CYCLE: REVERSE FAULTING

Tectonism associated with the collision of the Nazca and South American plates resulted in a period of extensional deformation in the Sierras Pampeanas region during the Neogene, followed by compression from the late Neogene through to the present. The extensional phase resulted in the development of a number of small southeast – northwest trending basins. Also during this period, high-K calc-alkaline to shoshonitic volcanics were emplaced in a ~80 km belt, parallel to the extensional basins, from Sierra del Morro to La Carolina,.

A marked change in the regional stress field occurred after the mid-Pliocene, coincident with the cessation of volcanism. Since that time, the Sierras Pampeanas region has been in a compressional regime and the Sierras de San Luis and Sierra de Comechingones are examples of the uplift on basement thrusts that have formed during this period (e.g., Costa and Vita-Frinzi, 1996). The ranges slope gently to the east and are bounded to the west by escarpments developed on low to moderate angle, east dipping, reverse faults. In the Sierra Comechingones, a major north-south fault zone, the Comechingones Fault (Costa and others, 1994), extends along the base of the western escarpment, and can be traced on aeromagnetic images to the south of La Punilla, beneath a veneer of Cainozoic sediments. ^{14}C ages suggest the fault was active as recently as c. 1000 years ago (Costa and Vita-Frinzi, 1996).

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 *Sierras de San Luis y Comechingones* 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) and the geological relationships, indicate that there are two principal domains in the southern Sierras Pampeanas: an older Cambrian domain, and a younger Cambro–Ordovician domain. Both domains share a common tectonic history since early Devonian times.

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 Valle de la Río Conlara and the Sierra de Comechingones (Conlara and Monte Guazú metamorphic complexes), as well as an orthogneiss dominated terrane with minor pelitic gneiss (the Nogoli Metamorphic Complex) in the western Sierras de San Luis. No original sedimentary structures, such as bedding, can be recognised in these metamorphic rocks. Minor marbles are common in the eastern complexes of the *Sierras de San Luis y Comechingones* but are less extensive than in interpreted extensions of the same domains in northern Córdoba (Lyons and others, 1997), where they form semi-continuous 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 540 Ma (Dalziel and others, 1994).

5.2 PAMPEAN CYCLE

Early Cambrian deformation, metamorphism, mafic and felsic intrusion

Following intrusion of tholeiitic mafic dykes, the sediments were deformed at mid-crustal levels by a compressive event (D1) and metamorphosed at mostly upper amphibolite facies and locally, granulite-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). 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 within the Monte Guazú Metamorphic Complex. There are no radiometric dates on these intrusions although similar intrusions in the Sierra Norte - Ascochinga area in Córdoba have been dated at ~515 Ma (AGSO - Subsecretaría de Minería, unpublished U-Pb zircon data).

5.3 EARLY PALAEOZOIC TUBIDITE SEDIMENTATION

Continental and arc derived pelitic turbidites were deposited in a probable back arc basin setting along the Pampean margin in the early Palaeozoic. Remnants of this back arc basin form the protoliths to the Pringles Metamorphic Complex in the Sierras de San Luis.

5.4 FAMATINIAN CYCLE

Early Ordovician deformation, metamorphism, mafic and felsic intrusion

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 (Pringles Metamorphic Complex) and the Cambrain basement during a widespread deformational, metamorphic and magmatic event known as the “Ciclo orogénico Famatiniano” (Aceñolaza and Toselli, 1976), Famatinian Orogen (eg. Dalla Salda and others, 1992) or “Ciclo Famatiniano” (Dalla Salda, 1987). The compressive deformation (D1 in the Cambro-Ordovician rocks, D2 in the Cambrian rocks), which occurred at mostly upper amphibolite facies and locally at granulite-facies, was accompanied by the development of kilometre-scale east-dipping ductile shear-zones with orthogonal, westerly-directed, thrust movement. A number of mafic/ultramafic bodies (the Las Aguilas Group) that intruded the sedimentary protolith to the Pringles Metamorphic Complex were involved in the deformation and represent a significant mantle-derived heat source contributing to the high temperature metamorphic conditions.

The high-grade metamorphic episode during the Famatinian cycle was closely followed by extensional tectonism under upper-greenschist-facies conditions accompanied by emplacement of S-type granite and pegmatite (undifferentiated granitoids and pegmatite). Extensional tectonism and granite emplacement were restricted to discrete belts and resulted in pervasive retrogression within those belts of the high-grade metamorphic assemblages. The low-grade San Luis Formation was probably deposited during this extensional phase. Igneous activity culminated at ~470 Ma in the emplacement of granodioritic to tonalitic intrusives (Tamboreo Granodiorite and Bemberg Suite) that are spatially restricted to within the San Luis Formation. U-Pb monazite data (Camacho and Ireland, 1997) from the Pringles Metamorphic Complex and U-Pb uraninite data (Linares, 1959) from pegmatites suggest the terrain had cooled through 600°C by ~450-460 Ma.

5.5 ACHALIAN CYCLE

Early Devonian deformation, metamorphism and granite intrusion

Resumption of convergence on the western margin of Gondwana in the mid Palaeozoic is evidenced by a widespread compressive deformation of the Ordovician cover sequence (San Luis Formation) and older crystalline basement, and 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 ductile and brittle-ductile, conjugate shear-zones. Locally, outside the principal shear zones, the basement and cover rocks were open to isoclinally folded and refolded with an axial planar crenulation surface developed in places. Dalla Salda (1987) defined this 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 intruded into the metamorphics discontinuously during and after shear zone development. Some of the shear zones (e.g. the Las Lajas Complex) were the locus of multiply injected subconcordant granite and later pegmatite intrusion. In other areas, circular, zoned, and fractionated plutons, commonly coalesced to form batholiths, and crosscut early, greenschist-facies shear-zones. Uranium-lead zircon dating of the granites suggests that initial plutonism was around 404 Ma (Camacho and Ireland, 1997). Ar-Ar ages from greenschist-facies mylonite zones and brittle-ductile strike-slip faults and fractures suggests that deformation continued through until ~355 Ma (Camacho, 1997), however, granite intrusion may have continued into the Caboniferous. The Achalian Cycle derives its name from the Achala Batholith, the largest of the Devonian Batholiths in the southern Sierras Pampeanas, which is exposed north of the Sierra de Comechingones in the Sierras Grandes. The 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.

5.6 CARBONIFEROUS - PERMIAN SEDIMENTATION

Following peneplanation, and later marine transgression, fluvio-lacustrine and shallow-marine sediments of the Paganzo Group (Gonzále and Aceñolaza, 1972) were deposited during the Carboniferous and Permian times. These sediments, which are not represented in *Sierras de San Luis y Comechingones* may have covered much of the crystalline basement, however, only remnant outcrops of the group are now preserved in narrow (<2 km wide) grabens. These grabens, possibly initiated during syn-sedimentary extensional faulting, were active after the cessation of sedimentation and prior to the Andean Cycle deformation. It is possible that these late-Palaeozoic sediments were first deposited in basins controlled by a regional wrench tectonic regime late in the Achalian cycle.

5.7 MESOZOIC SEDIMENTATION AND MAGMATISM

During the Early Cretaceous, extensional faulting, including probable reactivation of some basement faults along the eastern margin of the southern Sierras Pampeanas, 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. These extrusive occur to the north of *Sierras de San Luis y Comechingones* in both the Sierras de San Luis and the Sierras de Córdoba. Age determinations on the mafic rocks range from 150 Ma to 56 Ma (Linares and González, 1990).

5.8 ANDEAN CYCLE

During the Cainozoic, in the Sierras de San Luis and Valle de Río Conlara dominantly andesitic lavas extruded, doming basement rocks and forming volcanic edifices with extensive pyroclastic aprons. This magmatism, which is dated between 9.5 Ma and 1.9 Ma was probably related to an extensional phase following the development of flat subduction of the Nazca plate (Smalley and others, 1993) in the mid-Miocene. The cessation of magmatism is marked by the commensement of east-west compression that resulted in inversion of the Cretaceous basins (Schmidt, 1993) and block thrusting of the basement rocks, forming north-south oriented ranges, 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 a reactivated and long-lived history. Costa 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 3366-21 1:100 000 map area of San Luis contains a wide range of metallic and industrial mineral occurrences, including Ni-Cu-Co in the Las Aguilas - Virorco district, W in the Los Cocos districts, and widespread deposits of Be, Li, Nb, Ta, mica, feldspar and quartz.

Geological and resource data on mineral occurrences 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 map 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). Locational and commodity data for a number of mineral deposits in Departamento Pringles were derived from the CREA (1996) mineral deposit database. The positional accuracy of occurrences from this data source is estimated as ±400m.

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. Details on the geology and grade-tonnage data, where available, for specific mineral deposits may be found in the database. A 1:250 000 Metallogenic Map for the sierras de San Luis and Comechingones regions 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). Mineral potential maps for specific deposit types are also included in the Metallogenic Atlas for the Sierras Pampeanas project (Skirrow and Johnstone, 1997). A geographic information system (GIS) for the project includes all geology, geophysics and metallogenic coverages (Butrovski, 1997).

2. METALLIC MINERAL OCCURRENCES

2.1 NI-CU-CO (PGE-AU) DEPOSITS: LAS AGUILAS - VIRORCO DISTRICT

Regional setting: Mafic and ultramafic plutonic bodies up to 5 km in length crop out in an 80 km NNE trending belt in the Sierras de San Luis. The Las Aguilas and Virorco Ni-Cu prospects, located 40-45 km NE of the city of San Luis, are the best known deposits in the belt. The petrology of the mafic-ultramafic rocks and/or associated mineralisation have been described by numerous workers, including González Bonorino (1952), Pastore and Ruíz Huidobro (1952), Brodtkorb and others (1976), Sabalua and others (1981), Sabalua (1986), Brogioni (1992), Malvicini and Brogioni (1993), Brogioni and Ribot (1994) and Gervilla and others (1995).

The mafic-ultramafic bodies in the Las Aguilas - Virorco district occur within a belt of Cambro-Ordovician high grade metasedimentary gneisses and schists, orthogneiss, amphibolite and pegmatite of the Pringles Metamorphic Complex (Sims and others, 1997). An orthogneiss dated by U-Pb zircon methods at 484±7 Ma (Camacho and Ireland, 1997) suggests that metamorphism peaked at high grade in the early Ordovician. Magnetite is locally abundant in the high grade rocks, and together with the high magnetic susceptibility of the mafic-ultramafic bodies, has resulted in a broad regional magnetic domain of high amplitude within the Pringles Metamorphic Complex. The Las Aguilas deposit occurs towards the northwest margin of this magnetic domain.

U-Pb dating of zircons from a plagioclase-orthopyroxene magmatic segregation from the Las Aguilas Este mafic-ultramafic body indicates a crystallisation age of 478±6 Ma (Camacho and Ireland, 1997), which is within error of the inferred age of high grade metamorphism. The close temporal and spatial relationship between emplacement of the mafic-ultramafic complex and high grade metamorphism suggests these intrusive rocks may have been the heat source for the metamorphism (Sims and others, 1997).

Gneisses enclosing the Las Aguilas mafic-ultramafic rocks are mylonitic, with subvertical stretching lineations on a steeply dipping N-S foliation. Margins of the larger mafic-ultramafic bodies, and the centres as well as margins of the numerous lenticular smaller bodies, are recrystallised with high grade metamorphic textures and are foliated in places. The deformed margins led González Bonorino (1961) to suggest that emplacement of the intrusions commenced during deformation, an interpretation supported in the current studies (Sims and others, 1997). The smaller bodies are generally hornblende amphibolites, whereas the larger bodies at Las Aguilas consist of mainly norite (or melanorite) and pyroxenite with minor melagabbronorites, leuconorite, peridotite and dunite (Sabalua, 1986; Brogioni, 1992; Malvicini and Brogioni, 1993). Contacts are generally subvertical at Las Aguilas. Compositional layering is well exposed in subhorizontal 'strata' of mainly hornblende norite in the Virorco igneous body (González Bonorino, 1961).

Geology: Diamond drilling and surface mapping at the Las Aguilas Este body (Sabalua, 1986), which contains the most significant Ni-Cu-Co mineralisation discovered to date, indicates that the igneous rocks are zoned horizontally from east to west as follows: a thin pyroxenite margin; dunite; alternating pyroxenite and dunite units; pyroxenite; norite (or melanorite) with minor pyroxenite. Pyroxenite and melanorite exhibit cumulate textures involving orthopyroxene, plagioclase, hornblende and phlogopite (Malvicini and Brogioni, 1993). As part of our petrological investigations of the Las Aguilas Este deposit, textural studies of dunite and pyroxenite in drill hole 6/4 have revealed that fresh to partially serpentinised euhedral olivine, orthopyroxene and chromian spinel formed cumulates with interstitial net-textured, semi-massive or disseminated sulfides. The preserved primary magmatic cumulate textures and gross compositional zonation westwards from ultramafic to mafic rocks within the Las Aguilas Este body suggest, by comparison with mafic-ultramafic intrusions elsewhere (Naldrett, 1989), that the eastern contact may be close to the original base of the intrusion. Subsequent (and/or synchronous) deformation resulted in rotation of contacts to subvertical orientations as well as boudinage, shearing and possibly transposition of parts of the intrusion(s).

A resource of 2 220 000 tonnes @ 0.51% Ni, 0.50% Cu and 0.035% Co has been outlined in the Las Aguilas deposits (Sabalua, 1986). Zones of highest grade Ni (>0.5% to ~1.5%) correspond with those of Cu and Co in the Las Aguilas Este deposit, and occur predominantly in pyroxenite and dunite units towards the eastern contact (Fig. 1; Sabalua, 1986). Grade contours of Ni closely follow dunite and pyroxenite contacts in the lower portions of the explored deposit, but the contours evidently are discordant to these contacts in the upper levels where pyroxenite is the principal host to sulfide mineralisation. Based on observations in drill hole 5/2 which intersects the upper parts of the Las Aguilas Este deposit, Malvicini and Brogioni (1993) suggested the ore sulfides replaced silicates, and occur only in sheared igneous rocks. However, in deeper parts of the deposit (e.g drill holes 6/4, 6/W2) pyrrhotite, pentlandite and chalcopyrite are interstitial to well preserved cumulate olivine, orthopyroxene and chromian spinel in unfoliated dunite and pyroxenite, and show no evidence of replacement of the silicates. In these deeper zones veinlets of pyrrhotite and chalcopyrite cutting the silicates are volumetrically very minor, and represent local, limited, remobilisation of sulfides during post-crystallisation brittle deformation. It is possible that larger scale remobilisation of sulfides occurred in the upper parts of the deposit during deformation, although Sabalua (1986) described sulfides in the upper zones (e.g. drill hole 5/2) as massive and disseminated with only minor veins.

Minor tabular phlogopite occurs within the interstitial sulfides and at contacts of sulfides with olivine or orthopyroxene; in some cases it also occurs with clino-amphibole replacing pyroxenite (Malvicini and Brogioni, 1993). Other minerals occurring in the igneous rocks are: rare clinopyroxene, biotite, magnetite, ilmenite, and graphite which is conspicuous in some of the mylonitic gneisses close to the igneous bodies and within some leucocratic and sulfide mineralised igneous rocks. Late carbonate-pyrite-amphibole(?) veins and chlorite cut the igneous rocks.

In addition to the ore minerals mentioned, the following phases have been reported (Sabalua and others, 1981; Malvicini and Brogioni, 1993; Gervilla and others, 1995): gold, electrum, platinum-group minerals (PGM; tellurides and arsenic sulfides), cobaltite, cubanite, molybdenite, tellurobismutite, altaite, mackinawite. Pyrite, marcasite, goethite, hematite, greigite, violarite, bravoite, covellite and digenite are supergene alteration products. Native platinum and/or PGM occur in chromite (Sabalua and others, 1981; Malvicini and Brogioni, 1993) and in pyrrhotite, pentlandite and chalcopyrite (Gervilla and others, 1995). At least some PGM appear to postdate crystallisation of the mafic-ultramafic rocks (Gervilla and others, 1995), although PGM inclusions in chromite may be magmatic. Analyses of up to 2.8 ppm Pt, 0.5 ppm Pd and 0.3 ppm Au have been reported

(Sabalua and others, 1981; Malvicini and Brogioni, 1993), but precious metals have not been analysed systematically in drill holes.

Genesis: Whole rock and mineral chemistry of the igneous rocks at Las Aguilas indicate the parent magma was tholeiitic with SiO_2 content of ~52%, and may have been emplaced in a back-arc basin environment as it underwent deformation (Sabalua and others, 1981; Brogioni and Ribot, 1994; Skirrow, 1997a; Sims and others, 1997). As discussed by Skirrow (1997a), sulfides of Ni, Cu and Co are suggested to have formed by segregation from the mafic magma, and concentrated in cumulate zones within the igneous bodies. Remobilisation of ore elements during deformation varied in intensity across different parts of the igneous bodies.

2.2 W DEPOSITS: LOS COCOS DISTRICT

The Los Cocos district is the principle area of W deposits in the 3366-21 map area, and forms part of a 25 km long belt of W mineralisation between La Florida and Santo Domingo (Skirrow, 1997a). Although some of the main deposits have been located by GPS and many others have been located on airphotographs and their geographical coordinates measured, a number of occurrences necessarily have been grouped because of lack of accurate locational data. Groupings are based on those given in the data source (e.g. Ricci, 1971); such groups of occurrences have been assigned the coordinates of principal deposits in the group that have been located on airphotographs or by GPS (if any).

Three main styles of W mineralisation are present in the sierras de San Luis and Comechingones regions: (i) scheelite associated with quartz veinlets in generally low grade metasedimentary sequences, (ii) wolframite with minor sulfides in large quartz veins, and (iii) scheelite associated with calcsilicate rocks. Minor wolframite and scheelite also occur in pegmatites. Style (i) includes deposits in the La Florida - Los Cocos - Santo Domingo belt of the eastern Sierras de San Luis, and deposits in the Pancanta district south of La Carolina (Sheet 3366-15). Wolframite-quartz veins of style (ii) are evidently restricted to the La Carolina - San Román district. Type (iii) calcsilicate-associated scheelite occurrences are confined to mainly the Conlara Metamorphic Complex to the east of the Río Guzman Shear Zone where calcsilicate rocks, metacarbonates and amphibolites are intercalated with metapelitic rocks. The major districts of style (iii) W mineralisation are situated in the sierras del Morro, Los Morillos, Yulto and La Estanzuela.

Regional setting: The regional geology and structure of the La Florida - Pampa del Tamboreo - Santo Domingo region is complex (Sims and others, 1997). The Río Guzman Shear Zone marks the boundary between the early Ordovician San Luis Formation to the west and the Cambrian Conlara Metamorphic Complex to the east. The San Luis Formation is a sequence of metapelites, metapsammites and metaconglomerates that were deposited during and after Famatinian extension. Two main belts of San Luis Formation occur to the west of the Río Guzman Shear Zone, and represent thrust slices that developed during compressive deformation in the Devonian (Sims and others, 1997). The western of these two belts was dismembered by emplacement of the Escalerilla granite in the Devonian (U-Pb zircon age of 404±5 Ma, Camacho and Ireland, 1997). Tungsten deposits of styles (i) and (ii) are distributed preferentially in the San Luis Formation.

A zone of D_3 shears separate the San Luis Formation from metapsammites and metapelites of the Pringles Metamorphic Complex to the west, whose tectonic and metamorphic history differs from that of the younger San Luis Formation. These quartzo-feldspathic metasediments were initially metamorphosed to medium grade during D_1 in the early Ordovician, then intruded by extensive granitoids and tourmaline-bearing pegmatites during D_2 extension. The W deposits of the Los Cocos district occur in the Pringles Metamorphic Complex, 1-2 km west of the zone of D_3 shears mentioned above, which lie close to the eastern boundary of Sheet 3366-21 in the La Florida area.

Regional low grade retrogression accompanied D_2, resulting in widespread muscovite±tourmaline development in schists. Following deposition of the San Luis Formation late- to post-D_2, the Pampa del Tamboreo granodiorite was emplaced at 470±5 Ma (Camacho and Ireland, 1997), producing a contact metamorphic aureole in the San Luis Formation. A narrow area of this intrusion is exposed in the extreme northeastern limit of Sheet 3366-21. The Pampa del Tamboreo granodiorite and the San Luis Formation were intruded by numerous plagioclase-quartz porphyritic rhyolite dykes. The metasedimentary and igneous rocks were intensely deformed and metamorphosed to low grade during the Devonian $D_{3\text{-}4}$ compressive events, with strain generally localised in and near shear zones.

Although no Devonian granites are known to crop out in the the La Florida - Santo Domingo region, a broad zone of low aeromagnetic response occurs near La Florida and may represent a Devonian granite in the subsurface.

Geology: The geology and genesis of W deposits in this belt have been discussed by numerous workers, including Monchablon (1956), Stoll (1963a, b), Ambrosini and others (1981), Leveratto and Malvicini (1982), Carotti and others (1985), Brodtkorb and others (1984, 1985), Hack and others (1991), Fernandez and others (1991) and Ramos (1990, 1992).

The principal features that are shared by many of the W deposits in the La Florida - Los Cocos - Santo Domingo belt are as follows.

- Scheelite is the primary ore mineral
- The W mineralisation is associated with quartz veinlet networks or is disseminated
- Host rocks are part of the low grade metamorphic rocks of the San Luis Formation, except for some of the westernmost deposits in the belt (Los Cocos district)
- Deposits occur within or in proximity (<1 km) to zones of intense D_3 deformation
- Scheelite commonly occurs in feldspathic rock types such as plagioclase-quartz porphyry to aplitic bodies and meta-arkosic rocks
- Quartz veinlet networks are most intensely developed in relatively competant units where they are in contact with less competant rocks, for example metapsammite, quartzite or felsic porphyry/aplite within phyllite or metapelitic schist
- The mined zones are broadly confined to particular compositional layers but locally transgress layering
- Veins and veinlet networks are deformed and vein minerals are recystallised
- Sulfides and oxides are very low in abundance; pyrite, arsenopyrite, and ilmenite altered to rutile, occur at La Teodolina (Sheet 3366-16; Ramos, 1992; Brodtkorb and others, 1985), and pyrite is widespread (e.g. Carotti and others, 1985)
- Tourmaline and white mica commonly are very abundant in proximity to the quartz veinlet systems with scheelite mineralisation; calcsilicates such as epidote and titanite as well as apatite, fluorite and carbonate occur in veins and wall rocks with scheelite in some deposits (Brodtkorb and others, 1985; Carotti and others, 1985; Hack and others,

1991), and scapolite, hornblende and garnet were reported in scheelite-bearing quartzite host rocks in the Los Cocos district (Stoll, 1963a; Brodtkorb and others, 1985)

- Biotite is very abundant in mineralised zones of some but not all deposits (e.g. La Teodolina), and is partially chloritised

Other critical observations of relevance in understanding the timing and depositional controls of the W deposits are as follows.

- Felsic dykes (some previously interpreted as felsic volcanics, Brodtkorb and others, 1984) cutting the compositional layering in the San Luis Formation (e.g. at El Araucano, Sheet 3366-16) are mineralised with quartz-scheelite veins; these dykes are of identical texture and mineralogy to a dyke that intrudes the Pampa del Tamboreo granodiorite at Puesto Tito (Sheet 3366-21, 6342000N, 3500000E). A maximum age of 470±5 Ma is therefore suggested for the formation of quartz-scheelite veinlets.
- Relatively thin, fine to medium grained, feldspathic bands are present in the San Luis Formation (e.g. at La Riojita, Sheet 3366-16), and although they could represent metavolcanics, they are texturally distinct from the prominant porphyritic felsic bodies which at least in some cases are certainly dykes.
- Quartz veins containing scheelite at Fortuna (Sheet 3366-22) cross cut the Pampa del Tamboreo granodiorite, but xenoliths of biotite schist in the granodiorite are mineralised at Donosa (Sheet 3366-22; Brodtkorb and others, 1985).
- Intense D_{3-4} deformation has resulted in transposition of compositional layering in large parts of the San Luis Formation, so that many of the porphyritic felsic bands are parallel to both the main foliation and to compositional layering in the metasediments.
- Mineralised zones in some deposits are confined to structures interpreted to have formed during D_{3-4}, such as F_{3-4} fold hinges and F_{3-4} axial planes (e.g. Los Cocos, Fig. 3).
- Scheelite porphyroblasts in biotite schist at La Teodolina are wrapped by the main foliation which is a crenulation cleavage. Ramos (1992) suggested the scheelite porphyroblasts predated the crenulation cleavage; our observations concur with this conclusion, but we propose that the scheelite overgrew the earlier slatey cleavage. La Teodolina is situated within the D_{3-4} shear zone at the western contact of the San Luis Formation. Both foliations in this area are believed to have formed during D_{3-4}

progressive deformation and low grade metamorphism, in the Devonian (Sims and others, 1997), implying a Devonian age of scheelite growth at La Teodolina.

- Scheelite occurs in tourmaline-bearing pegmatites (e.g. La Teodolina, Ramos, 1992; and in mylonitic quartz-feldspar-tourmaline pegmatite at General Joffre, Sheet 3366-22), but the timing of pegmatite emplacement and of the scheelite in the pegmatites is not known.

Genesis: Previous interpretations of the timing and origin of W mineralisation in the La Florida - Los Cocos - Santo Domingo belt may be grouped into two main hypotheses.

1. The W was syngenetic, associated with felsic volcanism, and was remobilised during deformation and metamorphism (Brodtkorb and Brodtkorb, 1975, 1979; Brodtkorb and others, 1985; Fernandez and others, 1991; Hack and others, 1991).
2. The W was epigenetic-syndeformational and formed from pneumatolitic or hydrothermal fluids related to granites (Stoll, 1963a, b; Carotti and others, 1985). Smith and González (1947) noted that scheelite postdated aplite dykes at the Santo Domingo deposit.

An alternative hypothesis suggested by Skirrow (1997a) is that W was introduced by hydrothermal fluids into the San Luis Formation and schists immediately to the west (at Los Cocos) no earlier than ~470 Ma and most likely during the early Devonian, synchronous with D_3 compressive deformation. The major controls on localisation of scheelite were the presence of D_3 structures such as shear zones and folds, particularly where there were significant competancy contrasts between compositional layers. In the resultant dilational sites (felsic porphyry bodies, quartzites, granitoid contacts, etc), quartz±tourmaline±calcsilicate±fluorite vein networks developed. Scheelite precipitated preferentially in ‘chemical traps’: these consisted of calcic host rocks such as feldspar porphyry bodies, meta-arkosic layers and amphibole-bearing contact metamorphic zones (e.g. at the Pampa del Tamboreo granodiorite).

2.3 PEGMATITE-HOSTED DEPOSITS OF BE, LI, NB, TA, SN

Pegmatites in sheet 3366-21 host a number of significant sources of Be, Li and industrial minerals (e.g. mica, feldspar, quartz, etc.). One occurrence of Nb-Ta-Sn is also known.

The earliest pegmatites in the sierras de San Luis are interpreted to represent the melt products of the leucosome-forming reactions during high grade (upper amphibolite and granulite facies) metamorphism in both the Pampean and Famatinian cycles (see Sims and others, 1997). These generally small unmineralised garnet-bearing quartz-K-feldspar± plagioclase±biotite pegmatites are common in the Pringles Metamorphic Complex.

Herrera (1968) and Galliski (1993, 1994) described muscovite-rich K-feldspar-quartz pegmatites from other regions of the Sierras Pampeanas (type 2 of Herrera, 1968; transitional between muscovite and rare element classes of Cerný, 1991a, according to Galliski, 1993, 1994). These are a major economic source of muscovite, and relatively small examples may be present in the sierras de San Luis (e.g. López, 1984) but their tectonic-magmatic setting and genetic relationships to other pegmatite types within the map area are not well constrained.

Pegmatites of the rare element class of Cerný (1991a) (types 3 and 4 of Herrera, 1968) are widely represented in the sierras de San Luis. The deposits have been described by many workers including Herrera (1963, 1965, 1968), Angelelli and Rinaldi (1965), Arcidiácono (1974), Ortiz Suárez and Sosa (1991), Sosa (1990, 1991, 1993), Oyarzábal and Galliski (1993), and Galliski (1993, 1994). Examples of the beryl, complex (spodumene subtype) and albite-spodumene types of Cerný (1991a) have been recognised (Galliski, 1993), including cassiterite-bearing pegmatites (Sosa, 1990, 1991, 1993; Ortiz Suárez and Sosa, 1991). Internal zoning, dimensions, geometry and parageneses are described in the cited references.

In Sheet 3366-21 all but one of the documented Be and Li occurrences occur in the Pringles Metamorphic Complex, and are members of the rare element class of Cerný (1991a) or types 3 and 4 of Herrera (1968). They are most likely related to Famatinian magmatic and tectonic processes. One occurrence of Nb-Ta-Sn is present, evidently within the Escalerilla granite. An Achalian age of mineralisation is probable for this rare element occurrence, as for one Be occurrence located in this granite.

The timing, tectonic setting and magmatic affiliations of pegmatite types in the sierras de San Luis and Comechingones regions are further discussed in Skirrow (1997a) and Sims and others (1997).

2.4 FE, MN OCCURRENCES

One occurrence of each of these commodities has been documented in Sheet 3366-21. No descriptions of the geology are available.

3. NON-METALLIC MINERAL OCCURRENCES

3.1 MICA, QUARTZ, FELDSPAR

Numerous pegmatite bodies have been worked for muscovite, quartz and feldspar and occur widely in the map area. Many of those mined only for muscovite, quartz or feldspar probably are members of the muscovite or primitive rare element classes of pegmatites, and formed during the early Famatinian extensional tectonism. Some pegmatites mined for Be as well as muscovite, quartz or feldspar may be members of the rare element class of pegmatites.

BIBLIOGRAPHY

ACENOLAZA, F.G., y TOSELLI, A.J., 1976. Consideraciones estratigráficas y tectónicas sobre el Paleozóico inferior del Noroeste Argentino. Memoria, II Congreso Latinoamericano de Geología, 2, 755-764.

AMBROSINI, G.L., GONZALEZ, R., QUARTINO, B.J. y RINALDI, C.A., 1981. Mineralización de wolfram en el faldeo oriental de la Sierra de San Luis. VIII Congreso Geológico Argentino, Actas, IV: 623-630.

ANGELELLI, V., 1984. Yacimientos Metalíferos de la República Argentina I, II. Comisión de Investigaciones Científicas, Provincia de Buenos Aires.

ANGELELLI, V., y RINALDI, C.A., 1965. Reseña acerca de la estructura, mineralización y aprovechamiento de nuestras pegmatitas

ARCIDIACONO, E.C., 1974. Contribución al conocimiento de columbita-tantalitas de las provincias de Córdoba y San Luis. Asoc. Geol. Argent., Rev., 29(2): 171-184.

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

BRODTKORB, M.K. DE y BRODTKORB, A., 1975 (published in 1980). Especulaciones sobre un origen singenético-sedimentario de la scheelita presente en las metamorfitas del nordeste de la Provincia de San Luis. VI Congreso Geológico Argentino, Bahia Blanca, 1975, Actas 3: 37-50.

BRODTKORB, M.K. DE y BRODTKORB, A., 1979. Consideraciones genéticas de la scheelita presente en las metamorfitas de la provincia de San Luis. Asociación Geológica Argentina, Revista, 34(2): 131-140.

BRODTKORB, M.K. DE, DONNARI, E. y VILLAR, L.M., 1976. Estudio petrocalcográfico de la perforación VI del básico de Las Aguilas, Provincia de San Luis. Servicio Minero Nacional, Informe 1126, Buenos Aires.

BRODTKORB, M.K., DE, PEZZUTTI, N., y BRODTKORB, A., 1985. La franja con mineralización scheelítica entre el dique La Florida y Paso del Rey, Provincia de San Luis. Asociación Geológica Argentina, Revista, XL (1-2): 51-59.

BRODTKORB, M.K., DE, PEZZUTTI, N.E., y DALLA SALDA, L.H., 1984. Presencia de vulcanismo acido en el Precámbrico de la Provincia de San Luis. Noveno Congreso Geológico Argentino, Actas, 2: 181-190.

BROGIONI, N. y RIBOT, A., 1994. Petrología de los cuerpos La Melada y La Gruta, faja máfica-ultramáfica del borde oriental de la Sierra de San Luis. Asociación Geológica Argentina, Revista, 49: 269-283.

BROGIONI, N., 1988. Caracteres geológicos y clasificación de los domos volcánicos Mio-Pliocenos de San Luis. Revista del Museo de La Plata, Tomo 10 (84): 101-112.

BROGIONI, N., 1990. Geología y petrografia del vulcanismo Mio-Plioceno de la Provincia de San Luis. Revista del Museo de La Plata, Tomo 10 (90): 197-214.

BROGIONI, N., 1992. El cuerpo máfico-ultramáfico de Las Aguilas, Provincia de San Luis. Mineralogía de los silicatos. Primero Reunión de Mineralogía y Metalogenía y Primero Jornada de Mineralogía, Petrografía y Metalogénesis de rocas ultrabásicas, Actas: 379-392. La Plata.

BUTROVSKI, D., 1997. Geographic Information System (GIS) for the Sierras Pampeanas Mapping Project, Argentina. Geoscientific mapping of the Sierras Pampeanas, Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report. Arc/Info GIS.

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

CAROTTI, M., CONDE, S.A.R., MALLAVIABARRENA, M., y RINALDI, C.A., 1985. Características de los yacimientos de scheelita de La Pampa del Tamboreo, Provincia de San Luis. Actas del Noveno Congreso Geológico Argentino, Bariloche, 1984, 9(7): 220-230.

CERNY, P., 1991a. Rare-element granitic pegmatites. Part I: Anatomy and internal evolution of pegmatite deposits. Geoscience Canada, 18 (2): 49-67.

CERNY, P., 1991b. Rare-element granitic pegmatites. Part II: Regional to global environments and petrogenesis. Geoscience Canada, 18 (2): 68-81.

CERREDO, M., 1996. Metamorphic evolution of high grade metapelites of Sierra de Comechingones, Córdoba, Argentina. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 531.

COSTA, C.H. and VITA-FINZI, C., 1996. Late Holocene faulting in the southeast Sierras Pampeanas of Argentina. Geology, 24, 1127-1130.

COSTA, C.H., 1996. Analysis neotectónico 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.

COSTA, C.H., MURILLO, M.V., VITA-FINZI, C. and GARDINI, C.E., 1994. Quarternary folding and perspectives for paleoseismological studies in the southeastern Sierras Pampeanas, Argentina. In Prentice, C. Schwartz, D. and Yeats, R. (editors), Workshop on paleoseismology, U.S. Geological Survey Open-File Report, 94-568, 39-40.

CREA, 1996. Mineral resources database, Departamento Pringles. Microsoft Access / ArvViewII platform. Gobierno de Provincia de San Luis.

CRIADO ROQUE, P., MOMBRU, C. y RAMOS, V.A., 1981. Estructura y interpretación tectónica. In: Geología y recursos narurales de la Provincia de San Luis (edited by Yrigoyen, M), VIII Congreso Geológico Argentino Relat., 155-192.

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

DALLA SALDA, L., 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.

DALZIEL, I.W.D., DALLA SALDA, L.H. and GAHAGAN, L.M., 1994. Paleozoic Laurentia-Gondwana interaction and the origin of the Appalachian-Andean mountain System. Geological Society of America Bulletin, 106: 243-252.

DALZIEL, I.W.D., DALLA SALDA, L.H., CINGOLANI, C. and PALMER, P., 1996. The Argentine Precordillera: a Laurentian terrane? Penrose Conference Report, GSA Today, February 1996: 16-18.

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., Y KRAEMER, P.E., 1996. Caracterización y significado geotectónico de las fajas ultramáficas de las Sierras Pampeanas de Córdoba. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 421-438.

FERNANDEZ, R.R., PEZZUTTI, N., y BRODTKORB, M.K. DE, 1991. Geología, petrografía y yacimientos entre Pampa de Tamboreo - Paso del Rey - Santo Domingo, Provincia de San Luis. Publication del Instituto de Recursos Minerales, Universidad de La Plata, 1: 153-170.

GALLISKI, M.A., 1993. La Provincia Pegmatítica Pampeana. I: Tipología y distribución de sus distritos económicos. Asociación Geológica Argentina, Revista, 49: 99-112.

GALLISKI, M.A., 1994. La Provincia Pegmatítica Pampeana. II: Metalogénesis de sus distritos económicos. Asociación Geológica Argentina, Revista, 49: 113-122.

GERVILLA, F., SANCHEZ-AGUILA, A., ACEVEDO, R.D., y FENOLL HACH-ALI, P., 1995. Mineralogía de los elementos del grupo del platino del yacimiento Ni-Cu de Las Aguilas, Provincia de San Luis. Congreso Nacional de Geología Económica, San Juan, Secretaría de Minería de la Nación.

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

GONZALEZ BONORINO, F., 1961. Petrología de algunos cuerpos básicos de San Luis y las granulitas asociadas. Asociación Geológica Argentina, Revista, XVI(1-2): 61-106.

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

GRANT, J.A. 1985. Phase equilibria in low-pressure partial melting of pelitic rocks. American Journal of Science, 285, 409-435.

HACK, M., BRODTKORB, M.K. DE, HÖLL, R., y BRODTKORB, A., 1991. Geología y consideraciones genéticas de los yacimientos scheelíticos entre el dique La Florida y Pampa de Tamboreo, Provincia de San Luis. Publicación del Instituto de Recursos Minerales, Universidad de La Plata, 1: 113-152.

HERRERA, A.O., 1963. Las pegmatitas de la Sierra de San Luis: Estructura interna, mineralogía y génesis. Asociación Geológica Argentina, Revista, 18(1-2): 43-71.

HERRERA, A.O., 1965. Evolución geoquímica de las pegmatitas zonales de los principales distritos Argentinos. Asociación Geológica Argentina, Revista, 20: 2.

HERRERA, A.O., 1968. Geochemical evolution of zoned pegmatites of Argentina, Economic Geology, 63: 13-29.

HUNGERFORD, N., SIMS, J.P and STUART-SMITH, P.G., 1996. Magnetic interpretation - Sierras de San Luis y Comechingones. Australian Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report 30.

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., 1996. El magmatismo crecácico de las Sierras de Córdoba y sus implicancias tectónicas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 453-464.

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

LEVERATTO, M.A. y MALVICINI, L., 1982. Geología y génesis del yacimiento de wolfrámio El Duraznito, San Luis. Asociación Geológica Argentina, Revista, 37: 369-383.

LINARES, E. y GONZALES, R.R., 1990. Catalogo de edades radiométricas de la Republica Argentina. Años 1957 - 1987. Publicaciones especiales de la Asociación Geológica Argentina, Serie "B" (Didáctica y Complementaria). N° 19. 627pp.

LINARES, E., 1959. Los métodos geochronológicos y algunas edades de minerales de la Argentina, obtenidas por medio de la relación plomo-uranio. Asociación Geológica Argentina, Revista, 14: 181-217.

LLAMBIAS, E.J. y MALVICINI, L., 1982. Geología y génesis de los yacimientos de tungsteno de las Sierras del Morro, Los Morrillos y Yulto, Provincia de San Luis. Asociación Geológica Argentina, Revista, 37: 100-143.

LLAMBIAS, E.J., CINGOLANI, C., VARELA, R., PROZZI, C., ORTIZ SUAREZ, A., TOSELLI, A. y SAAVEDRA, J., 1991. Leucogranodioritas sin-cinemáticas ordovícicas en la Sierra de San Luis. VI Congreso Geológico Chileno Resúmenes Expandidos. 187-191.

LOPEZ, M.G., 1984. Relaciones petrológicas entre pegmatitas y sus cajas en la región de Tilisarao-Renca, Provincia de San Luis. Asociación Geológica Argentina, Revista, 39(1-2): 131-143.

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 Argentine-Australian 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.

MALVICINI, L. y BROGIONI, N., 1993. Petrología y génesis del yacimiento de sulfuros de Ni, Cu y platinoideos 'Las Aguilas Este', Provincia de San Luis. Asociación Geológica Argentina, Revista, 48: 3-20.

MARTINO, R., KRAEMER, P., ESCAYOLA, M., GIAMBASTIANI, M., y 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. IGCP 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.

MONCHABLON, A., 1956. Yacimientos de wolfrámio de la Provincia de San Luis, Dirección Nacional de Geología y Minería, Buenos Aires, inedito.

NALDRETT, A.T., 1989. Magmatic sulfide deposits. Clarendon Press - Oxford University Press, New York - Oxford.

ORTIZ SUAREZ, A., PROZZI, C. y LLAMBIAS, E.J., 1992. Geología de la parte sur de la Sierra de San Luis y granitoides asociados, Argentina. Estudios Geológicos, España, 48(5-6): 269-277.

ORTIZ SUAREZ, A.E. y SOSA, G.M., 1991. Relaciones genéticas entre las pegmatitas portadores de estaño y metamorfitas asociadas en la zona de La Carolina / San Francisco del Monte de Oro, Provincia de San Luis. Asociación Geológica Argentina, Revista, XLVI(3-4): 339-343.

OTAMENDI, J.E., NULLO, F.E., FAGIANO, M. y ARAGON, E., 1996. Dos Terrenos Metamórficos y estructurales en el extremo sur de la Sierra de Comechingones, Córdoba-San Luis: Algunas implicacias tectónicas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 249-266.

OYARZABAL, J.C. y GALLISKI, M.A., 1993. Geología del yacimiento San Luis: Un caso de yuxtaposición de tipologías diferentes en pegmatitas de clase elementos raras. XII Congreso Geológico Argentino, Actas, V: 167-174.

PASTORE, F. y GONZALES, R.L., 1954. Descripcíon geológica de la Hoja 23g, San Francisco (San Luis). Dirreccíon Nacional de Minería, República Argentina, 80, 62p.

PASTORE, F. y RUIZ HUIDOBRO, O.J., 1952. Descripcíon geológica de la Hoja 24g, Saladillo (San Luis). Dirrección Nacional de Minería, República Argentina, 78, 63p.

PIETERS, P., SKIRROW, R.G. and LYONS, P., 1997. Report on Geology and Metallogeny of the Sierras de Las Minas, Chepes and Los Llanos 1:250 000 map sheet, Province of La Rioja. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

PINOTTI, L.P., CONIGLIO, J.E., y LLAMBIAS, E.J., 1996. Características geológico-estructurales del Plutón Alpa-Corral, 32°8’ - 32°47’S y 64°55’ - 64°45’W, Sierras Pampeanas de Córdoba, Argentina. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III: 477-486.

PROZZI, C.R. y RAMOS, G. 1988. La Formación San Luis. I Jornadas de trabajo de Sierras Pampeanas, San Luis.

RAMOS, G.A., 1990. Estudios preliminares sobre el control estructural en la mina de scheelita ‘La Teodolina’, Provincia de San Luis, Argentina. Decimo Primer Congreso Geológico Argentino, San Juan, 1990, Actas, 1: 357-360.

RAMOS, G.A., 1992. Caracteres estructurales de algunas manifestaciones de scheelita en la zona de la Mina 'La Teodolina', San Luis, Argentina. In: BRODTKORB, M.K. DE y SCHALAMUK, I.B. (eds.), I Reunión de mineralogía y metalogenía, La Plata, 1991. Instituto de Recursos Minerales, Universidad Nacional de La Plata, No. 2: 237-247.

RAMOS, V., 1988. Late Proterozoic - Early Paleozoic of South America - a collisional history. Episodes, 11(3): 168-174.

RAPELA, C.W., and PANKHURST, R.J., 1996. The Cambrian plutonism of the Sierras de Cordoba: pre-Famatinian subduction? and crustal melting. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 491.

RICCI, S.M., 1971. Provincia de San Luis - Mapa Minero, Escala 1:750 000. Ministero de Indústria y Minería, Subsecretaría de Minería, Dirección Nacional de Promoción Minera.

SABALUA, J., CHABERT, M., y SANTAMARIA, G., 1981. Mineralización de sulfuros de hierro, cobre y niquel, en el cuerpo basico de Las Aguilas, Provincia de San Luis. VIII Congreso Geológico Argentino, San Luis, Actas, IV: 497-507.

SABALUA, J.C., 1986. Yacimiento Las Aguilas: Mineralización Ni-Cu-Co, Departamento Pringles, Provincia de San Luis, República Argentina, Dirección General de Fabricaciones Militares, Subdirección de Desarrollo Minero, Centro de Exploración Geológico Minera, 29p.

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.

SATO, A.M., ORTIZ SUAREZ, A., LLAMBIAS, E.J., CAVAROZZI, C.E., SANCHEZ, V., VARELA, R., y PROZZI C., 1996. Los plutones pre-Ocloyicos del sur de la Sierra de San Luis: Arco magmático al inicio del ciclo Famatiniano. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 259-272.

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

SIMS, J., SKIRROW, R.G., STUART-SMITH, P.G. and LYONS, P., 1997. Report on Geology and Metallogeny of the “Sierras de San Luis y Comechingones” 1:250 000 map sheet, Provinces of San Luis and Córdoba. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

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.

SKIRROW, R.G., 1997a. Economic Geology of the Sierras de San Luis and Comechingones 1:250 000 map sheet. *In:* SIMS, J., SKIRROW, R.G., STUART-SMITH, P.G. and LYONS, P., 1997, Report on Geology and Metallogeny of the “Sierras de San Luis y Comechingones” 1:250 000 map sheet, Provinces of San Luis and Córdoba. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

SKIRROW, R.G., 1997b. Economic Geology of the Sierras Septentrionales de Córdoba 1:250 000 map sheet. *In:* 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 Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

SKIRROW, R.G., 1997c. Economic Geology of the Sierras de Las Minas, Chepes and Los Llanos 1:250 000 map sheet. *In:* PIETERS, P., SKIRROW, R.G. and LYONS, P., 1997, Report on Geology and Metallogeny of the Sierras de Las Minas, Chepes and Los Llanos 1:250 000 map sheet, Province of La Rioja. Geoscientific Mapping of the Sierras Pampeanas Argentine-Australian Cooperative Project, Australian Geological Survey Organisation, unpublished report.

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

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

SMALLEY, R. Jr., PUJOL, J., REGNEIR, M., CHIU, J.M., CHATELAIN, J.L., ISACKS, B.L., ARAUJO, M. and PUEBLA, N., 1993., Basement seismicity beneath the Andean Precordillera thin-skinned thrust belt and implications for crustal and lithospheric behaviouor. Tectonics, 12, 63-76.

SMITH, W.C. and GONZALES, E.M., 1947. Tungsten investigations in the Republic of Argentina, 1942-43, U.S. Geological Survey Bulletin, 954-A:1-37.

SOSA, G.M, 1991. Pegmatitas portadoras de estaño de la Provincia de San Luis: Su geología, mineralogía y génesis. Primero Reunión de Mineralogía y Metalogenía, La Plata, Instituto de Recursos Minerales, Universidad Nacional de La Plata, Actas, (2): 379-392.

SOSA, G.M., 1990. Relaciones entre las pegmatitas portadores de estaño y las portadoras de niobio-tantalo de la Provincia de San Luis. Decimo Primer Congreso Geológico Argentino, San Juan, 1990, Actas, 1: 366-368.

SOSA, G.M., 1993. Pegmatita estannífera compleja mina ‘Victor Hugo’, Provincia de San Luis. XII Congreso Geológico Argentino, Actas, V: 159-166.

SOSIC, M., 1964. Descripción geológica de la Hoja 24 h - Sierra del Morro, San Luis-Córdoba. Dirreccíon Nacional Geología y Minería, Buenos Aires, 95, 44p

SPEAR, F.S., 1981. An experimental study of hornblende stability and compositional variability in amphibolite. AmericanJournal of Science, 281, 697-734.

SPEAR, F.S., 1993. Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America, Monograph. 799pp.

STOLL, W.C., 1963a. Los yacimientos de scheelita de Cerro Los Cocos (Provincia de San Luis), Asociación Geológica Argentina, Revista, 18(3-4): 116-120.

STOLL, W.C., 1963b. La geología del tungsteno en Argentina. Asociación Geológica Argentina, Revista, 18(1-2): 96-106.

STRASSER, E.N., TOGNELLI, G.C., CHIESA, J.O. y PRADO, J.L., 1996. Estratigrafia y sedimentología de los depositos eólicos 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., DURAND, F.R., ROSSI DE TOSELLI, J.N., y SAAVEDRA, J., 1996. Esquema de evolución geotectónica y magmática eopaleozóica del Sistema de Famatina y sectores de Sierras Pampeanas. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V: 443-462.

VON GOSEN, W. and PROZZI, C., 1996. Geology, structure and metamorphism in the area south of La Carolina (Sierra de San Luis, Argentina). XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas II: 301-314.

ZARDINI, R., 1966. Composición, estructura y origen de la Pampa del Tamboreo (provincia de San Luis). Acta Geológica Lilloana, 8, 50-73.

ARGMIN

MINERAL DEPOSIT DATABASE

OUTPUT DATA SHEETS