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Sedimentology of the Upper Cretaceous Red Beds of Angostura Colorada Formation in The Western Sector of The Northpatagonian Massif, Argentina

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Abstract — Detailed sedimentological analysis of the Angostura Colorada Fm. (Upper Cretaceous) in the Comallo Jacobacci Gastre areas of the western sector of the North Patagonian Massif has enabled the definition of three members based on sedimentary structures, paleocurrents, grain size, compositional characteristics and lithofacies associations . These members are: lower (alluvial fan), middle (sandy braidplain) and upper (flood plain) developed within a rift sequence.

Compositionally, two alternating source rocks are shown in the geological record, a continental block and recycled orogen provenance for the lower and middle members (Jacobacci area) and magmatic arc provenance for the middle (Gastre area) and upper members. This is interpreted as a progressive magmatism towards the K-T boundary during the rising of the Andean Cordillera to the west. The granitic provenance is attributed to igneous bodies of Paleozoic age to the N and SW of the study area. The smectite-zeolite rich clay mineral association of the upper member is interpreted as product of alteration of thick pyroclastic deposits.

The paleogeography of this unit includes two different paleodepositional systems, to the SW an alluvial fan system running from the SW to the NE, to the NE a sandy braided river running from the NW to the SE, perpendicular to the previous one in a wide paleovalley. Later flood plain and lacustrine shaley deposits developed to the east which are equivalent to the Alamitos Fm.

This distribution of paleodepositional systems is coherent with the main structural trends within the study area. A late Campanian age is assigned to this unit. © 1997 Published by Elsevier Science Ltd. All rights reserved

Resumen — El análisis detallado de la Fm. Angostura Colorada (Cretácico superior) en la región de Comallo Jacobacci Gastre aflorante en el sector occidental del Macizo Nordpatagónico ha permitido la definición de tres miembros en base a las estructuras sedimentarias, paleocorrientes, granulometría y características composicionales y litofaciales. Estas litofacies se agrupan en tres asociaciones principales de facies: abanico aluvial (miembro inferior), rios entrelazados arenosos (miembro medio) y planicie de inundación (miembro superior) desarrolladas dentro de una secuencia de rift.

Composicionalmente, dos áreas de aporte alternativas se muestran en el registro geológico, bloque continental y orógeno reciclado para inferior (área Gastre) y medio (área Jacobacci) y arco magmático para el medio (área Gastre) y superior (áreas Comallo-Gastre). Esto se interpreta como un progresivo magmatismo hacia el límite Cretácico Terciario durante el levantamiento del Cordón Andino hacia el oeste. La procedencia granítica se atribuye a los cuerpos graníticos de edad Paleozoica aflorantes hacia el norte y oeste del área de estudio. La asociación esmectita-ceolita en las facies finas del miembro superior, se interpreta como el producto de alteración de depósitos piroclásticos de gran espesor.

La paleogeografía de esta unidad muestra a dos sistemas paleodepositacionales diferentes, hacia el SO un abanico aluvial que desagua hacia el NE, hacia el NE un sistema de rios entrelazados que desagua hacia el SE y que corre perpendicular al sistema anterior dentro de un amplio paleovalle. Posteriormente, depósitos de planicie de inundación se desarrollan hacia el este, los mismos son equivalentes a la Fm. Los Alamitos.

Estos sistemas paleodepositacionales presentan una distribución areal coherente con los principales lineamientos tectónicos del área estudiada.Se asigna en forma tentativa, una edad Campaniana tardía a esta unidad.

INTRODUCTION

In this contribution the Angostura Colorada Fm., outcropping mainly in three different sectors is described (Fig. 1):

a) A western sector of approximately 100 km^2 along the Comallo Creek, in the Province of Río Negro, known as the Neneo Ruca area; b) An eastern sector close to the town of Ingeniero Jacobacci, in the same Province (Fig 3a); c) A southern sector to the west of the town of Gastre, in the Province of Chubut.

Cazau and Uliana (1972), Malumian *et al.*, (1983), Macellari (1988), Codignotto *et al.* (1978), among others, described upper Cretaceous red beds in the Neuquen and Chubut Groups outcropping to the north and south of the North Patagonian Massif respectively, based on abundant surface and subsurface data (chart 1). Malumian *et al.* (1983) show a paleogeographical distribution of red beds for the Upper Cretaceous in South America; on the other hand, Macellari (1988) emphasizes the importance and lateral extent of these facies (more than 500000 km^2) in the geological record during the Campanian Maastrichtian, specially in northern South America (western Venezuela to Peru).

In spite of all these information, the Angostura Colorada Fm. in the western sector of the North Patagonian Massif, described first by Volkheimer (1973) remains as a broad unit that correlates with the Neuquen Group to the north and with the Chubut Group to the south, because of the lack of biostratigraphical information and detailed geological study (chart 1).

Different authors have provided mapping reports and contributions on this unit, like: Feruglio (1949), Cazau

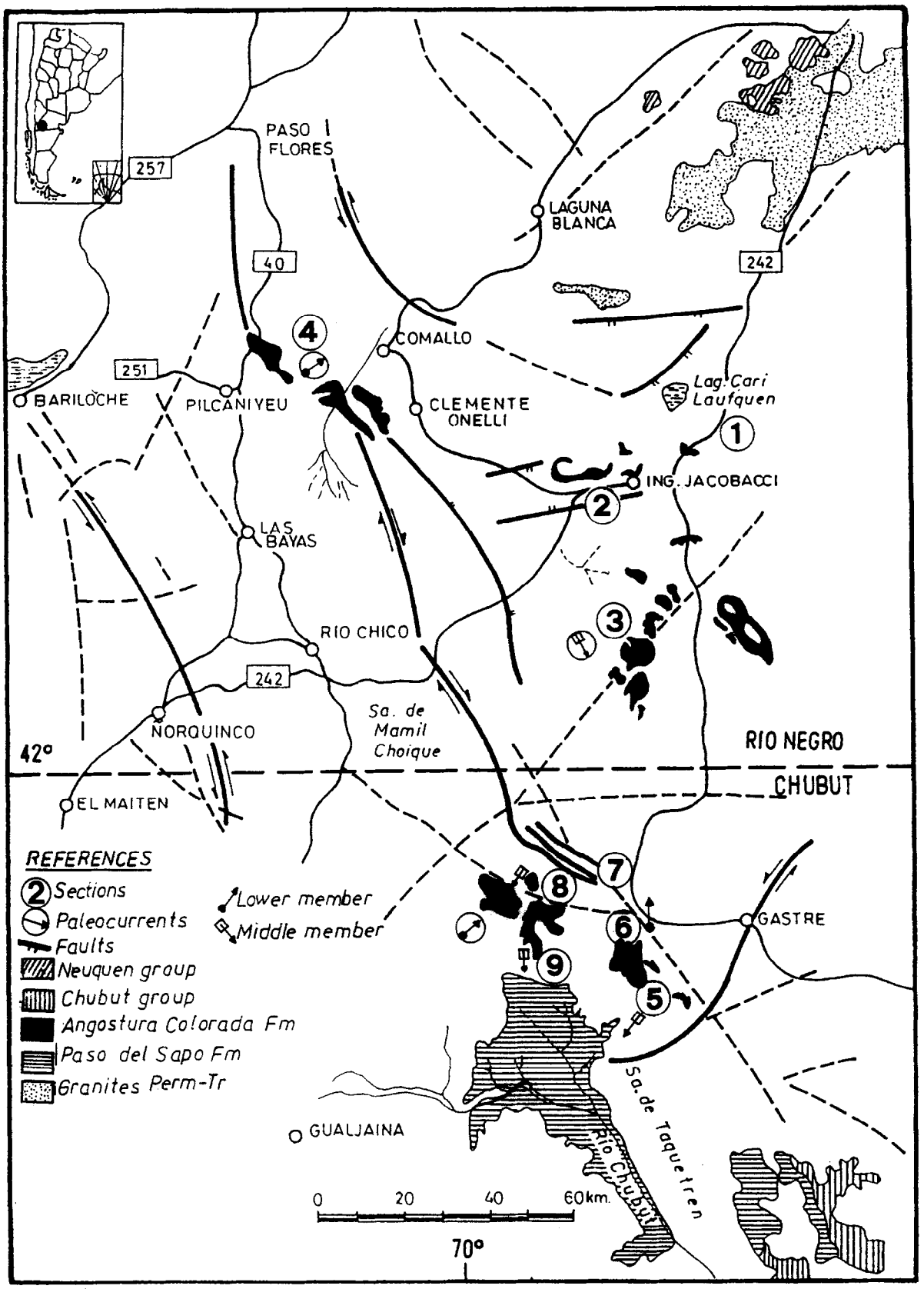

Fig. 1. Location of the study area, principal structural lineations and measured sections.

(1972), Dessanti (1972), Volkheimer (1973), Rabassa (1974, 1978), Coira (1979), Nullo (1978), Proserpio (1978), Spalletti *et al.* (1987) and Manassero and Maggi (1995). In the last paper we started this research in the Comallo area, and here we both add the geological information of the Gastre area and evaluate all the available data.

Nine sections have been measured and described (Figs. 1 and 2) in three areas: a) section 1 in the Comallo area, b)

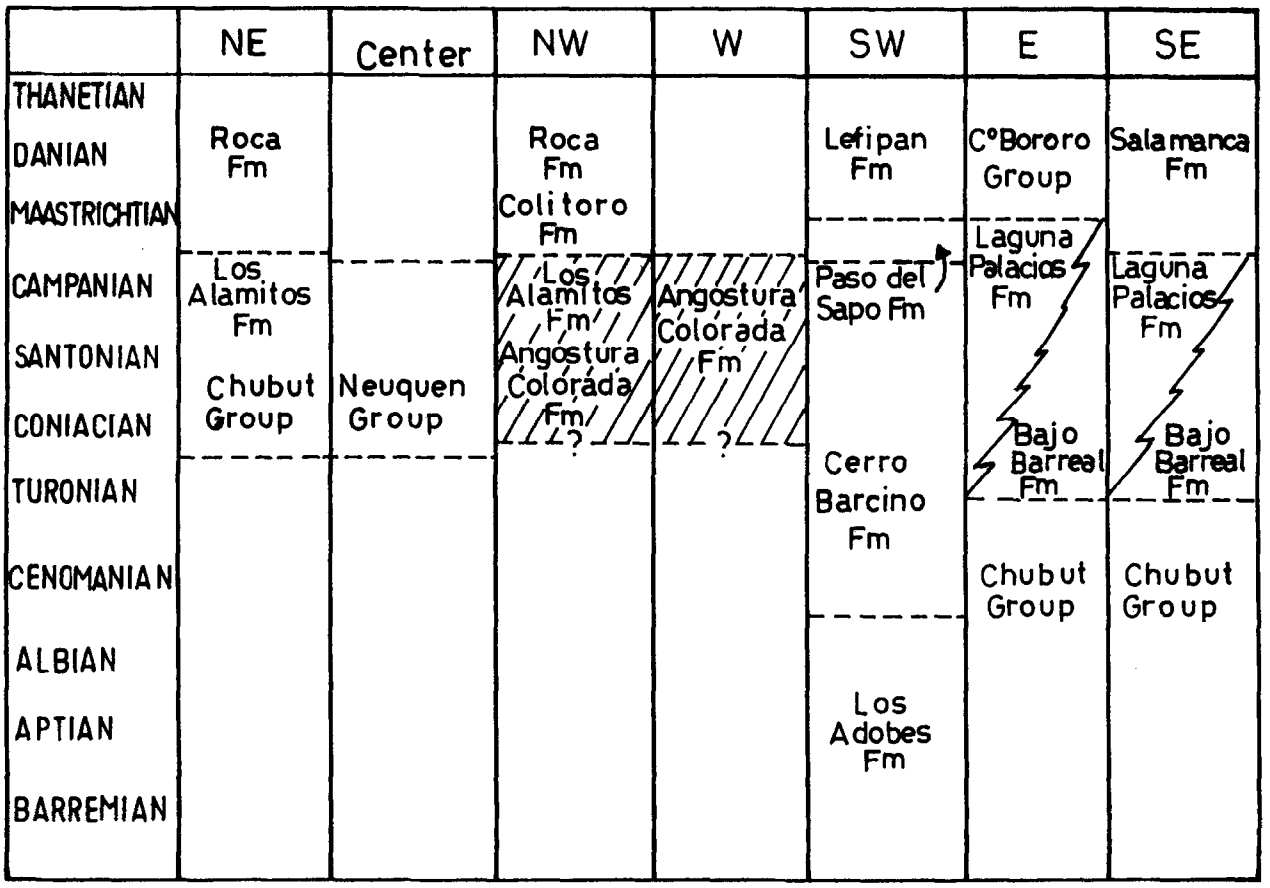

Chart 1. Correlation of Upper Cretaceous units of the North Patagonian Massif (Project 123-Northpatagonian Massiff-Centro Investigaciones Geológicas).

section 2, 3 and 4 in the Ing. Jacobacci area, c) sections 5, 6, 7, 8 and 9 in the Gastre area.

The sandstones have been studied for detrital modes and the shales have been analysed by X ray diffraction.

SECTIONS AND LITHOFACIES

The sections have been described and correlated on the basis of lithology, grain size, lithofacies, and paleocurrents (Fig. 2). The sequence was divided in three members, a lower member dominated by conglomerates, a middle member composed mainly of sandstones and an upper member composed mostly of shale. In spite of the poor exposure (Figs 1 and 2), these members were described along the basin following the lithofacies model of Miall (1977, 1978). The lithofacies characteristics are summarized in chart 2:

Fm: shale with massive structure, dark reddish colors predominate, interpreted as low energy deposits in a flood plain. Within this facies paleosols suggest subaerial exposure.

Fl: shale with horizontal lamination, tabular geometries, interpreted as overbank, lacustrine and flood plain deposits.

Sg: coarse and medium sandstone with graded structure interpreted as deposited in longitudinal and transverse bars.

Sr: medium to fine sandstone with oscillatory ripples typical of low energy deposits in a shallow water environment.

Sp: medium to coarse sandstone with planar cross stratification (Fig 3b), lenticular geometries produced by 2D megaripple migration that form amalgamated channels and bars. In some cases, abundance of trace fossils (epichnia).

Sh: fine micaceous sandstone with horizontal lamination produced by high and low flow regimes.

Sm: massive sandstones that form channels and bars within a braided system. Light reddish colors predominate.

St: medium to coarse sandstones with trough cross bedding (Fig 3d) produced by dune migration under low flow regime conditions.

Gm: clast supported conglomerates graded or massive (Fig 3c), with lenticular geometries (8 m wide, 2 m thick) with quartz, granitic and volcanic clasts (size 10–15 cm), interpreted as alluvial fan deposits.

Gms: chaotic matrix supported conglomerates associated to mass flow processes.

Although these lithofacies are present in most of the sections, the conglomerates and shales are more abundant in the area of Comallo and Gastre whereas the sandy facies are widespread in the Ing. Jacobacci area (Fig. 2).

The basal coarse facies are related to alluvial fan progradation in response to rejuvenation of source relief, the

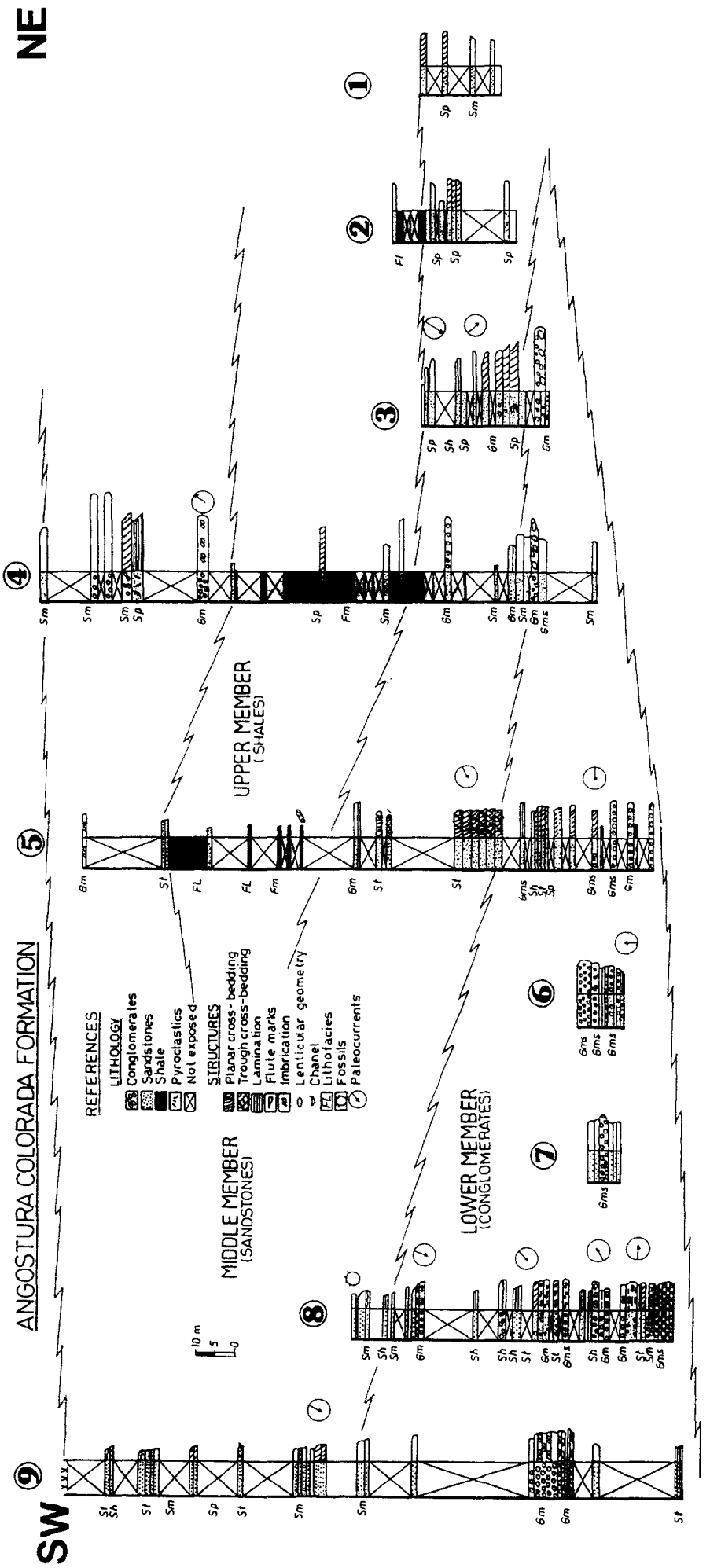

Fig. 2. Sedimentary structures, grain size, paleocurrents, lithofacies and correlation of the studieds ections.

Lithofacies	Lithology-grain size	Sedimentary Structures	Interpretation
Gms	Matrix supported Conglomerate size 5-7 cm.	None	Mass flow processes
Gm	Clast supported Conglomerate size 10-15 cm.	Massive or imbrication	Alluvial Fan Deposits
Sm	Sandstone	Massive	Channels and bars in braided system
Sh	Sandstone and mudstone	Horizontal lamination	Lamination in high and low flow regime
Sp	Medium Sandstone	Planar cross stratification	Migration of 2D megaripples
Sr	Medium to fine sandstone	Ripples	Oscillatory flow in shallow water
St	Medium to coarse sandstone	Trough cross bedding	Dunes in lower flow regime
Sg	Coarse and medium sandstone	Graded	Longitudinal and transverse bars
Fl	Shale	Lamination	Overbank and lacustrine deposits, flood plain
Fm	Shale	Massive	Flood plain-paleosol

Chart 2. Lithofacies description and interpretation (Miall, 1977, 1978).

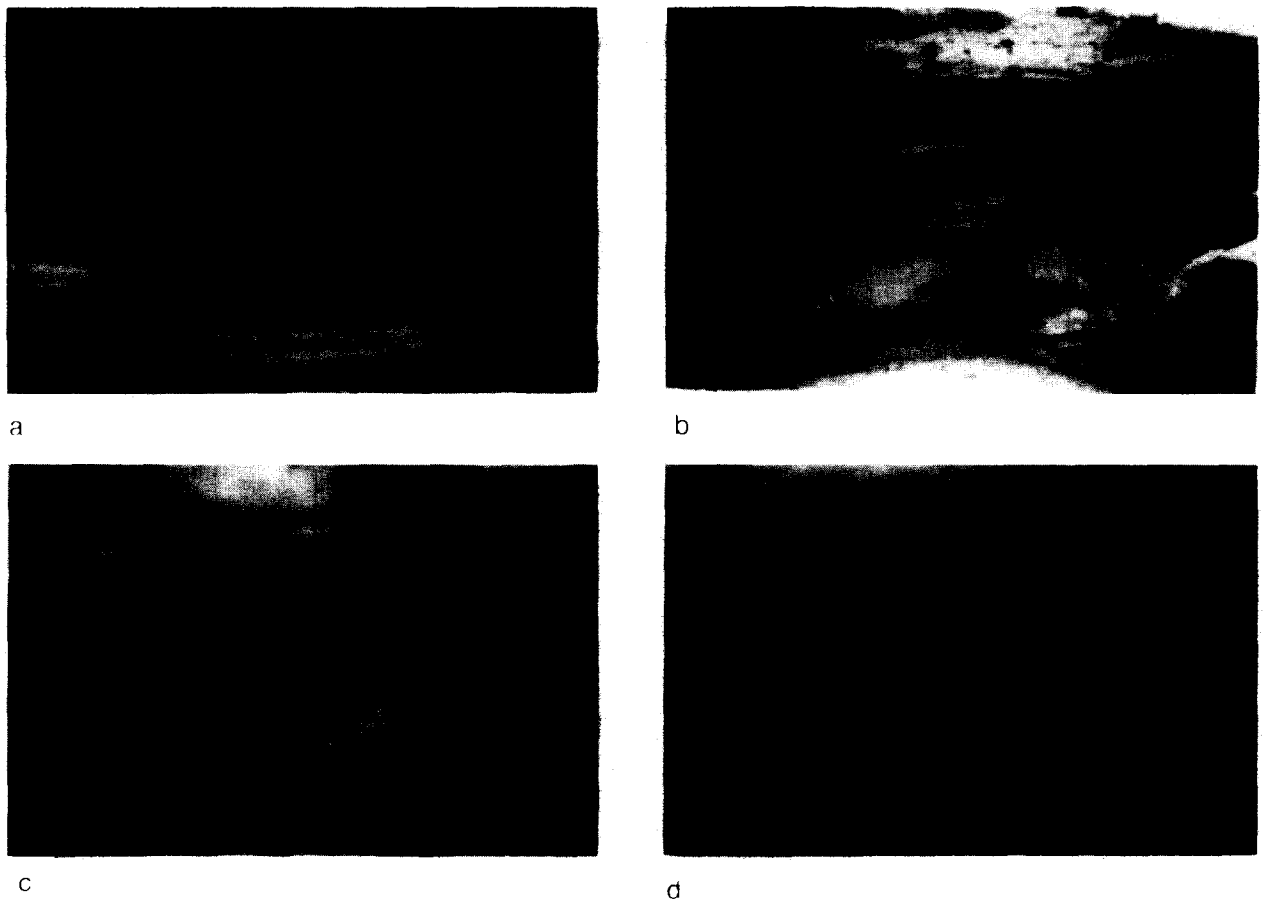

Fig. 3. a) General view of the Angostura Colorada Fm in section 3. b) Sp lithofacies within the middle member (Section 2). c) Sm and Gm lithofacies within the lower member (Section 9). d) St lithofacies to the base of the middle member in Section 5.

sandstones of the middle member are interpreted as a braided system with gradual migration and abandonment of channels with decreasing sediment supply that evolves to a flood plain environment with shaley facies.

Paleocurrents: although directional sedimentary structures are a good tool to discover the provenances, we do not have, in this study, a statistically significant number of data. In spite of this fact and based on available unidirecional structures (clast imbrication, flute casts, cross stratification) and bidirectional structures (channel axis, symmetric ripples), the lower member (Figs. 1 and 2) shows paleocurrents from SW to NE whereas the middle member has dominant paleocurrents from the NW to the SE.

At the top of the Angostura Colorada Fm., in section 9, we observe an angular unconformity beneath the overlying marine and subhorizontal Paso del Sapo Fm. (Spalletti, 1996). We attribute this unconformity to a tectonic event at the end of the Neuqueniano cycle (Uliana and Dellape, 1981) during the late Campanian.

CLAY ANALYSIS

Clays are tipically a major component of fluvial and lacustrine rift sequences. They are often impure as a result of deposition in a shallow water environment like swamps, flood plains or lakes.

Semiquantitative analysis was performed following Moore and Reynolds (1989). Thirty samples have been treated (normal, glycolated and calcinated) in order to recognize the clay mineral associations.

Two different clay mineral associations have been detected, one rich in smectite and the other rich in kaolinite. The former is generated by alteration of volcanic rocks, the second one, by weathering of acid plutonic rocks (Potter *et al.*, 1980, Iñiguez *et al.*, 1989, Manassero *et al.*, 1991). These clay associations show coherent links with the sandstone petrofacies depicting the same sources. The smectite suite is characteristic of the middle and upper members whereas the kaolinite one is restricted to the area of Jacobacci within the middle member.

Some of the conclusions of the clay mineral analysis are:

1) The smectite suite is dominant and widespread in the areas of Comallo and Gastre.

2) The shales show important mixing with claysized quartz and feldspars, reaching only 30 to 40% of clays minerals in each sample. This is explained by the mixing of mud and silt sizes produced by the transport agent within the flood plain. For this reason the clays are not of sufficient quality for economical applications.

3) Gypsum, suggesting important evaporation in shallow ponds, is present in some samples. Precipitation of

authigenic minerals is produced by the interaction of alkaline carbonate brines with the volcanogenic sediments that fills evaporitic rifts basins (Tiercelin, 1991), these minerals include zeolites such as analcime.

4) To the top of the sequence in the Gastre area, analcime is abundant, interpreted as deposited in shallow and saline ponds, with pyroclastic input (Surdam and Shepard, 1978).

SANDSTONE PETROGRAPHY

Forty four sandstone samples of the Angostura Colorada Fm. have been studied, 400 points were counted in each sample using the traditional method (Zuffa, 1984). The minerals recorded are: quartz (monocrystalline, polycrystalline, volcanic and metamorphic), K feldspar and microcline, plagioclase, biotite, muscovite, opaques, hematite and metamorphic, volcanic and sedimentary rock fragments. The most typical volcanic rock fragments, are laths of plagioclase set in a very finely crystalline matrix; these laths of plagioclase are both twinned and untwinned and present either a pilotaxic (oriented) or felsitic (unoriented) texture, typical of andesitic or trachytic rocks.

These data are plotted in ternary QFL diagrams (Fig. 4) following the method of Dickinson and Suczek (1979), and Dickinson *et al.* (1983). The samples are feldspathic and lithic arenites and wackes (Folk, 1968). In the ternary diagram the grouping of samples suggest a strong association of the samples from the lower member with the fields of continental block and recycled orogen while samples from the middle and upper members in general fall in the field of the magmatic arc suite. The middle member in the Jacobacci area shows a strong grouping of the samples in the field of continental block, this is explained by a granitic input from the north.

PALEOGEOGRAPHY AND PROVENANCE

Many papers have provided useful background for alluvial facies analysis with practical examples for the facies interpretation of the Angostura Colorada Fm., among others Brown and Plint (1994), Dreyer (1993), Reinfelds and Nanson (1993), Rust (1978), etc.

To resolve the question of provenance and to determine the geologic evolution of the area, the space and time distribution of the facies must be considered.

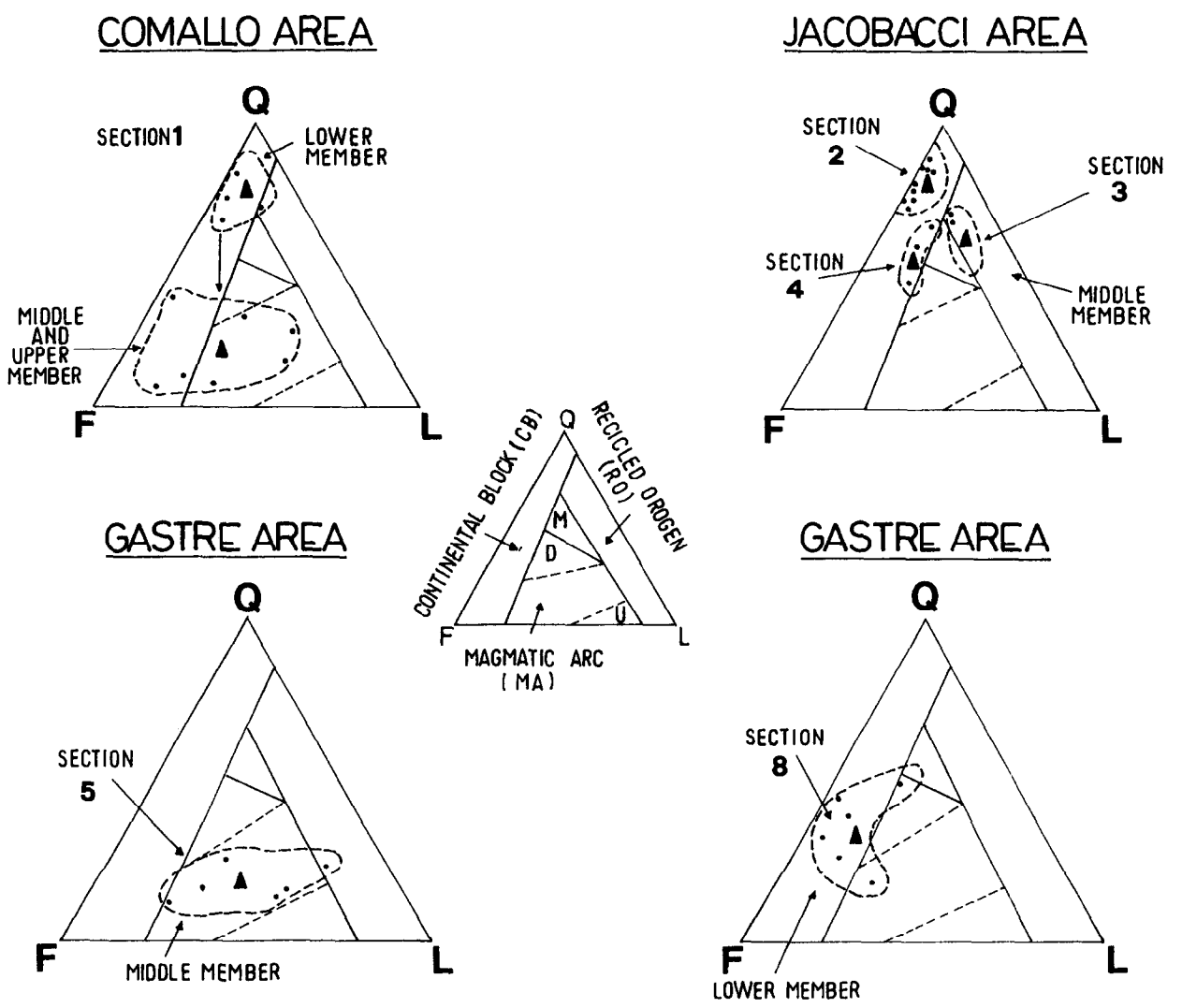

Fig. 4. Provenance QFL diagrams (Dickinson and Suczek, 1979, Dickinson *et al.*, 1983) for the Angostura Colorada Fm.

In Figs. 5 and 6 we can see how the arrangement of the main paleodepositional systems are displayed, based on paleocurrent data and compositional trends. The lower member deposited during the opening of the basin, with a granitc source terrain to the SW is characteristic of the southwestern sector of the study area, while a braided system running from the NW to the SE (middle member) was developed in a valley perpendicular to the previous depositional system. Later, a low energy deposition took place as flood plain and lacustrine deposits during the final basin filling stage. This upper member was correlated with Los Alamitos Fm. (Getino, 1995) outcropping to the NE of the study area.

The source areas for the lower member are the granitic terrains to the SW, the middle member has the same kind of source terrain to the north in the area of Jacobacci.

On the other hand, the volcanic rock fragments show two different sources:

1) In general terms there is a relative increase in volcanics towards the top of the unit. This is explained by a progressive input of clastics from the emerging Andean Cordillera to the west along with a synchronous and increasing volcanic activity. This proto-Andean source seems to dominate during the final filling basin stage.

2) To the bottom of the Angostura Colorada Fm., there is also a local input of volcanic detritus related to the first stages of the filling of the basin (see Manassero and Maggi, 1995) from older volcanic rocks, like the Comallo Beds (Rabassa, 1975) to the north and the Taquetrén Fm. (Proserpio, 1978) to the south of the study area. This local paleovolcanic source is also composed mainly by similar andesites and pyroclastics but with zoned laths of plagioclases and coarser grain size (coarse to very coarse sandstone), like in Section 6, with sources in the Taquetrén Fm. outcropping inmediately to the south.

This paleodepositional system distribution displayed along a rift valley is coherent (Fig. 1) with the main structural elements of the area.

CONCLUSIONS

1-The Angostura Colorada Fm., a 180 meters thick unit, comprises far more than the 40 m of sandy facies of the middle member described in its type locality (Section 3).

2-The Angostura Colorada Fm is composed by alluvial conglomerates, fluvial sanstones and shales within a rift sequence, and is divided in three members on the basis of the predominance of these lithologies. The lower member

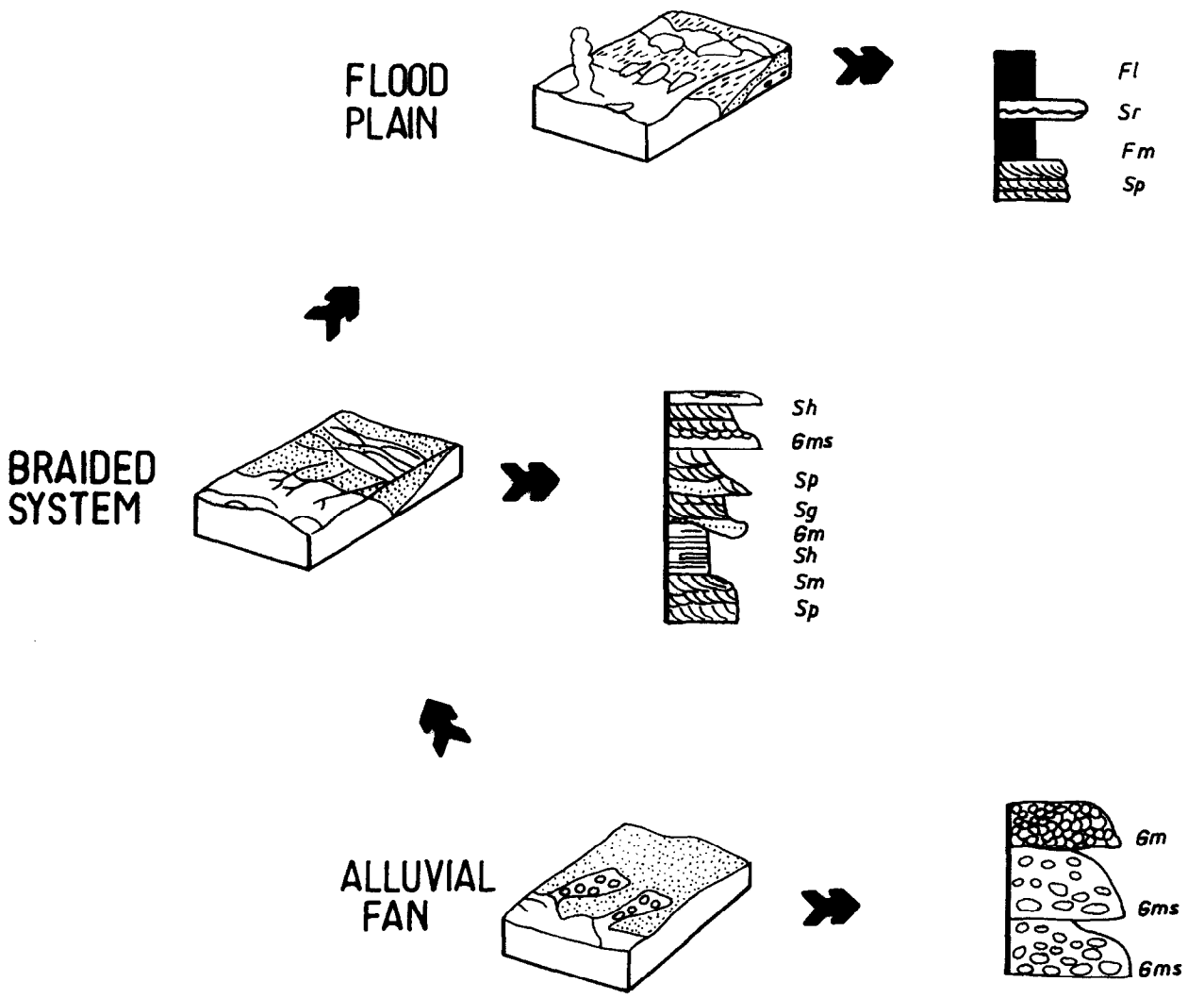

Fig. 5. Facies associations within the lower, middle and upper members and depositional environments.

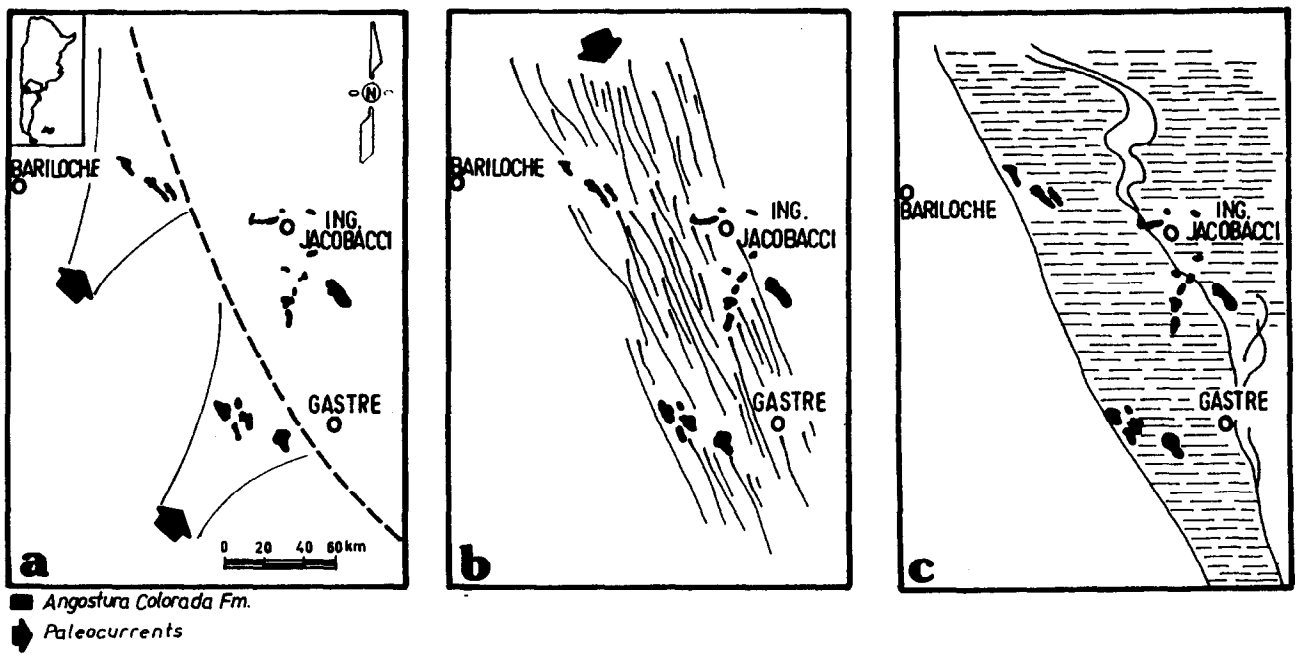

Fig. 6. Paleogeography and paleodepositional systems for the Angostura Colorada Fm. a—basin opening stage, b—main braided system stage, c—basin final filling stage

is composed of alluvial fan gravels, the middle by sandstones deposited in a braided system and the upper member by shales deposited in a flood plain. These members show vertical and lateral variations.

3-The petrographic study of the Angostura Colorada Fm. has shown two different sources, continental block and recycled orogen provenances for the lower member and the middle member (Jacobacci area) and magmatic arc provenance for the middle (Gastre area) and upper member. This is explained by a progressive increase of the volcanic of and pyroclastic input towards the top of the sequence coming from the west, during the rising of the Andean Cordillera. There was, then, a contemporaneous magmatism during the deposition of the Middle and Upper members of the Angostura Colorada Fm. which is also reflected by the clay mineral association within the Upper Member.

At the bottom of the Angostura Colorada Fm., we found a paleovolcanic and local input coming from older volcanic units that outcrop within the study area (Comallo Beds and Taquetrén Fm.) with similar andesitic composition but coarser grain size.

4-The upper member composed by a smectite-zeolite clay mineral association is a product of the alteration of these fine clastics and pyroclastics. This member is correlated with the Los Alamitos Fm.

5-The source areas for the continental block provenance are located to the north and southwest of the study area, they are mainly granites of Paleozoic age.

6-The paleogeography of the Angostura Colorada Fm. is interpreted as the interaction of two different paleodepositional systems, an alluvial fan system coming from the SW associated to the opening of the basin and a sandy braided system running from the NW to the SE within a wide rift river valley, perpendicular to the previous system. Shally facies develop later during a final filling basin stage, in the same area, with the development of flood plain deposits.

7-The deposition of this unit was controled by the main structural trends of the study area.

8-Although biostratigraphical data are not available, this unit is tentatively assigned to the late Campanian based on its stratigraphical position.

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