XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos
Actas T° I: (218-225)

SEDIMENTOLOGY AND ARCHITECTURE OF PROXIMAL EPHEMERAL SANDFLAT DEPOSITS IN A FORELAND BASIN SETTING. THE QUEBRADA DEL CURA AND LOWER RÍO JÁCHAL FORMATIONS (MIOCENE), SIERRA DE HUACO, SAN JUAN, ARGENTINA.

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RESUMEN. Se presentan los resultados de un trabajo llevado a cabo en la cuenca de antepaís del Bermejo, en el área de la Sierra de Huaco, Provincia de San Juan, Argentina. En esta localidad afloran 5,5 Km de rocas continentales asignadas al Mioceno. La columna estratigráfica local se divide en cinco unidades formacionales que de base a techo son: Fm. Jarillal, Fm. Huachipampa, Fm. Quebrada del Cura, Fm. Río Jáchal y Fm. Mogna. El presente trabajo está restringido únicamente al estudio de las características sedimentológicas y arquitectónicas de 1,4 Km de depósitos fluviales correspondientes a las formaciones Quebrada del Cura y Río Jáchal.

Cuatro tipos principales de depósitos fluviales han sido reconocidos en el campo, ellos son: cuerpos arenosos compuestos (multistorey channel sandstone bodies), cuerpos arenosos cordoniformes (ribbon sandstone bodies), cuerpos arenosos mantiformes (tabular sandstone sheets) y cuerpos arenosos mantiformes con barras de arena (sandstone sheets with sandstone bars). Estos depósitos fluviales se originaron en un ambiente de sedimentación árido, de ríos efímeros, en la parte proximal de una planicie arenosa (sandflat) anexa al extremo distal de un abanico aluvial. La sedimentación en este ambiente estuvo ampliamente dominada por el efecto de crecientes efímeras a veces restringidas a una red de canales entrelazados, sobre todo en la parte más proximal de la planicie arenosa, pero más comúnmente consistente en flujos mantiformes no confinados, especialmente en las zonas más distales.

INTRODUCTION

This paper presents the results of a study carried out in the Sierra de Huaco area, Bermejo Foreland Basin, western Argentina on a series of Miocene sedimentary rocks deposited in an ephemeral sandflat environment. Previous studies in the area focused on the overall stratigraphic characteristics of the 5.5 km thick Tertiary section at Sierra de Huaco and its age determination by magnetic polarity stratigraphy and fission track methods (Johnsson *et al.*, 1984, Johnson *et al.*, 1986, Beer *et al.*, 1987). Detailed sedimentologic and stratigraphic studies were only available for the lowermost part of the Tertiary section, specifically the Jarillal and Huachipampa Formations (Johnson *et al.*, 1986, Beer and Jordan, 1989). In this paper, it is my intention to complement these studies by concentrating on the sedimentology and architecture of the Quebrada del Cura and Lower Río Jáchal Formations, two of the units in the upper part of the local stratigraphic column.

Studies of alluvial sedimentology and architecture have been carried out in a broad range of tectonic settings, including rift and foreland basins. Studies of alluvial sequences in foreland basins have described thick clastic wedges deposited in advance of thrust fronts in orogenic belts like the Himalayas and Pyrenees (Behrensmeyer and Tauxe, 1982, Nichols, 1987). Many such studies have concentrated upon sandy or conglomeratic proximal successions while finer grained deposits of distal foreland basin areas have been less studied, commonly because of poorer outcrop conditions. Two examples of these type of studies are those of Beer and Jordan (1989) and Platt and Keller (1992). The present study of the Tertiary section cropping out in Sierra de Huaco is intended as a contribution to the available data on alluvial sedimentation and architecture in a distal alluvial fan setting under arid climatic conditions.

The strata in the study area are composed of major, laterally extensive sandstone bodies with intercalated intervals dominated by mudstones, with an average sandstone/ mudstone ratio of 3/1. Excellent exposures in the Sierra de Huaco allowed description of the geometry and stacking of the sandstone bodies along strike, together with the most important changes in large-scale bedding geometry, grain size, and sedimentary structures. Major sandstone bodies are tens of meters thick and are continuous along strike for many kilometers. Four different types of major sandstone bodies have been recognized : 1) multistorey channel sandstone bodies, 2) ribbon sandstone bodies, 3) tabular sandstone sheets, and 4) sandstone sheets with sandstone bars. Strata between major sandstone bodies are dominated by overbank mudstone beds which can be meters thick and can extend along strike for many kilometers. Some paleosols occur locally in the fine-grained facies but a reliable identification of the exact paleosol type is difficult due to the poor development of pedogenic structures.

The stratigraphic section studied is located in the central part of Sierra de Huaco, about 20 km SE of the town of Huaco. The section was measured and described on the eastern flank of the Las Salinas anticline, where strata strike NNE and dip 60-65° to the SE and are little deformed. Stratigraphic thicknesses were measured using a tape and compass survey, traversing the section at right angles. The section was measured in two legs selected for ease of access through actively dissecting streams and for good outcrop exposures. The two legs have a 40 m overlap of the Upper Quebrada del Cura Formation which allows their physical correlation. Detailed descriptions and interpretations of vertical variations in large-scale bedding geometry, grain size, and sedimentary structures were made along this section. Complete exposure for tens of kilometers along strike allowed definition of sandstone body boundaries from air photos, TM LANDSAT images, and along strike tracing of the beds in the field. Rock samples were collected along the section for sandstone composition and clast provenance studies. Seven paleomagnetic sites were sampled in order to secure correlation of the lower half of the measured section to the local magnetic stratigraphic column defined by Johnson *et al.* (1986). The base of the section ties with the magnetic polarity column that Beer and Jordan's (1989) designated as Huaco South, and therefore the same name was kept to designate the studied section (Fig. 3). The top of the measured section ties with the lower part of Johnsson's *et al.* (1984) magnetic polarity and Johnson's *et al.* (1986) Section I (Fig. 3).

SIERRA DE HUACO. GEOLOGIC SETTING

Location and Tectonic Setting

The studied 1.4 km thick stratigraphic section is located at Sierra de Huaco, San Juan Province, Argentina (Fig. 1). The Sierra de Huaco area consists of two north-trending anticlines and one associated syncline located in the Eastern Precordillera, a structural province comprising the west-verging, easternmost belt of the Precordillera thin-skinned fold and thrust belt (Ortiz and Zambrano, 1981). The measured section is located exactly in the eastern flank of the Las Salinas anticline (Fig. 2). The Las Salinas anticline is a fault propagation fold with strata in its eastern limb striking NNE with a dip 60-65° to the SE. Cross section balancing of the structures at Sierra de Huaco indicates a horizontal shortening of 10 km (Zapata and Allmendinger, 1993). The original location of the Quebrada del Cura and Lower Río Jáchal during the Miocene was then at least 10 km to the East of their present location. Some minor strike-slip faults and folds also affect the eastern flank of the Las Salinas anticline. These structures were taken into account when selecting the location of the measured cross section.

Figure 1: Location map of sierra de Huaco, San Juan, Argentina. The simplified geologic map shows the main tectonic elements associated with the studied area. Box indicate the approximate limits of figure 2. Inset map shows location in Argentina. Map modified from Jordan *et al.* (1993).

Stratigraphy

The rocks exposed at Sierra de Huaco record continuous sedimentation between 14-2.3 Ma (Johnson *et al.*, 1986). Five formations are recognized; from the base upwards they are: Jarillal, Huachipampa, Quebrada del Cura, Río Jáchal and Mogna. The Río Jáchal Formation has been traditionally divided by some authors in two members, a lower or sandy member and an upper or conglomeratic member. Only the lowermost sandy member was included in this study so that it will be referred in this paper as the Lower Río Jáchal Formation. All of the units are continental, fluvial strata comprised mainly of sandstone, siltstone, conglomerate, and minor claystone deposited under arid climatic conditions. Sedimentary environments ranged from braided ephemeral streams with channelized flow, to alluvial fan and sandflat environments with unconfined sheet flow (Beer and Jordan, 1989). The age of strata in the studied cross section were

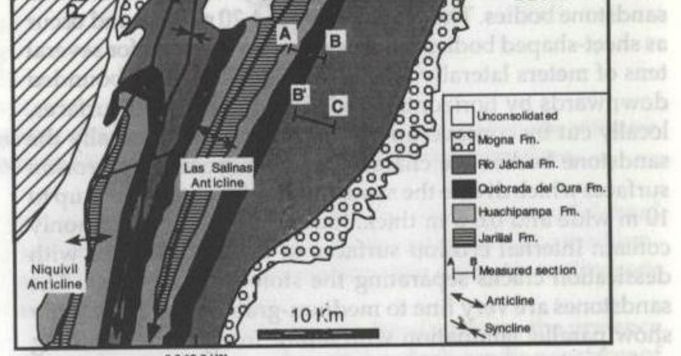

Figure 2: Geologic map of the Sierra de Huaco. The location and orientation of the studied cross section is indicated. Point B in cross section leg AB ties southward with point B' in leg B'C. Map modified from Beer and Jordan (1989).

derived from magnetic polarity stratigraphy (Fig. 3). Six magnetic reversals were determined at the Huaco South section and correlated with the magnetic polarity stratigraphy of Johnson *et al.* (1986) for the whole Neogene section at the Sierra de Huaco. The ages of the studied strata span a period of 2.5 Ma, from about 8 Ma for the base of the Quebrada del Cura Formation (Fig. 3) to 5.5 Ma at the upper limit of the Lower Río Jáchal Formation (Johnson *et al.*, 1986). The Huaco South Section ties with the magnetic polarity stratigraphy of Johnson *et al.* (1986, their Section I) at the Quebrada del Cura-Lower Río Jáchal (RJ/Q) boundary (Fig. 3). The age of 8 Ma for the base of the Quebrada del Cura Formation comes from direct correlation of the Huaco South Section magnetic polarity stratigraphy with the global magnetic polarity time scale. The age of 5.5 Ma for the upper limit of the Lower Río Jáchal Formation was derived from Johnson *et al.* (1986) Section I.

FLUVIAL SANDSTONE DEPOSITS

Four main types of fluvial sandstone deposits occur in the Quebrada del Cura and Lower Río Jáchal Formations: multistorey channel sandstone bodies, ribbon sandstone bodies, tabular sandstone sheets, and sandstone sheets with sandstone bars.

The deposits were defined on the basis of internal bounding surfaces according to the classification system of Miall (1985, 1988). Multistorey channel sandstone bodies are characterized by internal fifth-order bounding surfaces, confining individual storeys or channel-fill complexes. Ribbon sandstone bodies are bounded by fifth-order surfaces and exhibit internal surfaces no higher than third order. Tabular sandstone sheets possess internal surfaces of no higher order than second order (coset bounding surfaces). Sandstone sheets with sandstone bars show up to fourth order internal bounding surfaces (upper surfaces of macroforms elements). A synthesis of the most important sedimentologic characteristics and architectural elements of the sandstone deposits is shown in Table 1.

Multistorey channel sandstone bodies (Fig. 3, CH)*

This sandstone body type forms less than 20% of the total sandstone bodies. The sandstones are 4-20 m thick and occur as sheet-shaped bodies which exhibit no thinning for several tens of meters laterally. The sandstone-bodies are bounded downwards by horizontal eroded and noneroded surfaces, locally cut by concave-up erosional surfaces. Internally the sandstone bodies are characterized by concave-up erosion surfaces which divide the sandstone bodies into storeys up to 10 m wide and 0.6-5 m thick. Individual storeys commonly contain internal erosion surfaces or mudstone layers with dessication cracks separating the storeys into bedsets. The sandstones are very fine to medium-grained and commonly show parallel lamination with minor trough cross-bedding and cross lamination (Fig. 4). Each storey is interpreted as a channel-fill deposit. Lateral accretion bedding was not observed in the storeys suggesting that channel scouring and plugging dominated over lateral channel migration and deposition.

Some of the general characteristics of the multistorey channel sandstone bodies resemble the inferred braided stream deposits described by Allen (1983), for example their sheet geometry, multistorey composition and dominance of parallel lamination. They differ from Allen's sandstone bodies in the fact that these multistorey channel sandstone bodies lie on planar, smooth, horizontal surfaces of sixth-order (Miall, 1988), only cut locally by minor channel scours. This scarcity of basal scour surfaces might record an initiation of the braided stream system by sheetfloods, as suggested by Olsen (1989).

*Ribbon sandstone bodies (Fig. 3, CH**)*

This sandstone body type forms generally up to 10% of the fluvial sandstone deposits. The sandstone bodies commonly display an uneven and step-like scoured surface at the base of a 1-6 m thick, 5-6 m wide main sandstone body and a set of thin sandstone sheets or wings that extend laterally away from the central sandstone body for approximately 150-300 m perpendicular to the local paleoflow direction. The ribbon sandstone bodies are bounded below by concave-up erosion surfaces. Individual ribbon sandstone bodies are composed of several bedsets separated by thin desiccated siltstone layers and/or erosion surfaces. The ribbon sandstone bodies are composed of very fine and fine-grained sandstones. Parallel lamination and cross-lamination dominate, with trough cross-bedding locally present. The ribbon sandstone bodies occasionally fine upwards, in places associated with a change from trough cross-bedding to cross-lamination (Fig. 4).

The ribbon sandstone bodies resemble ancient solitary-channel ephemeral stream deposits like those described by Puigdefabregas (1973), Friend *et al.*, (1979), and Stear (1983). The basal erosion surfaces are fifth-order bounding surfaces of Miall (1988). Internal first- to third-order bounding surfaces occur in the main sandstone bodies but there is a lack of lateral accretion surfaces. Ribbon sandstone bodies similar to these were interpreted by Friend *et al.* (1979) as representing straight or slightly sinuous ephemeral channels that were scoured and plugged during repetitive flash-flooding events. Successive episodes of scouring were controlled to a large degree by the position of previously formed sand bodies so that the geometry of the ribbon, as a whole, reflects the geometry of the original channeling event (Stear, 1983). The frequent development of wings in the Quebrada del Cura and Lower Río Jáchal ribbon sandstone bodies must indicate that overbank flooding was a common feature. Channelization was probably the initial form of flow but was accompanied in most cases by extensive sheet-flooding outside the channels.

Tabular sandstone sheets (Fig. 3, LS)

Tabular sandstone sheets are the dominant fluvial deposits, comprising 60-70% of the fluvial sandstone deposits of the Quebrada del Cura and Río Jáchal Formations. Tabular sandstone sheets range in thickness from a few centimeters to a maximum of 8 m. Individual tabular sandstone sheets that are among the thicker examples extend several hundred meters transverse to local paleocurrent directions. Tabular

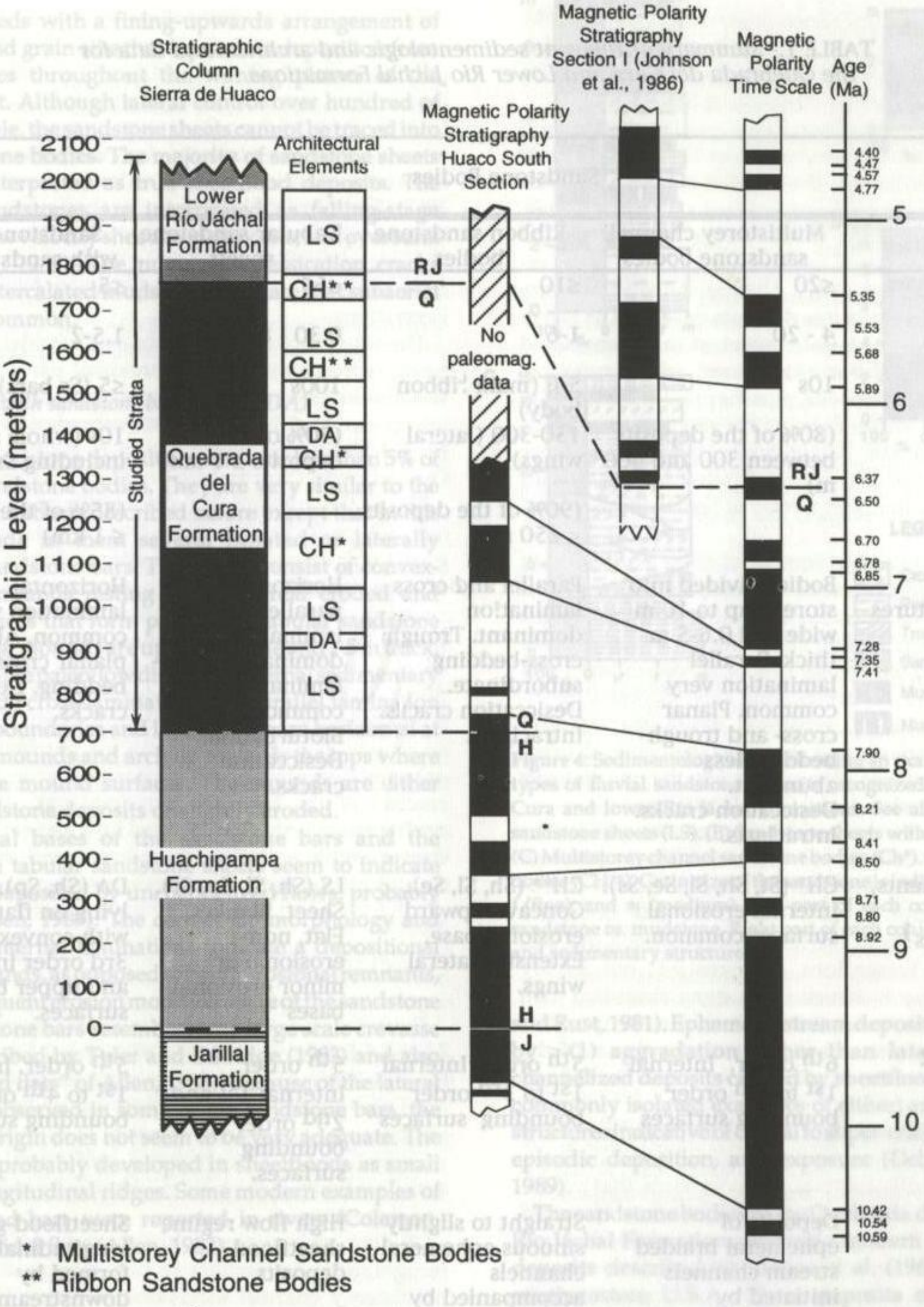

Figure 3: Lithostratigraphic units at Sierra de Huaco, magnetic polariy stratigraphy of Huaco South section, magnetic polarity stratigraphy of Section I of Johnson et al. (1986), and distribution of the main architectural elements in the Quebrada del Cura and Lower Río Jáchal Formations.

sandstone sheets occur as bedsets separated by mudstones and sand-streaked mudstones up to 1.5 m thick. It is also common that tabular sandstone sheets occur as stacked successions up to 10 m thick with only thin mudstone partings. Sandstone sheets rest on flat eroded and noneroded surfaces and posses horizontal tabular sheet geometries. The tabular beds within these sandstone are dominated by horizontal, parallel lamination. Locally the horizontal lamination exhibits upward transition to cross-lamination (Fig. 4). Bioturbation is abundant and commonly partly destroys the internal sedimentary structures. The sandstones are fine to medium-grained and some individual beds fine upwards to silty very fine-grained sandstones.

The flat and laterally extensive basal surfaces, the presence internally of only first and second-order bounding surfaces of Miall (1988), the absence of lateral accretion bedding, and the tabular geometry of the sandstones indicate deposition by sheetfloods. This is also complemented by the common

TABLE 1.- *Summary of relevant sedimentologic and architectural data for the Quebrada del Cura and Lower Río Jáchal Formations*

	Sandstone Bodies			
	Multistorey channel sandstone bodies	Ribbon sandstone bodies	Tabular sandstone sheets	Sandstone sheets with sandstone bars
Abundance (%)	≤20	≤10	≤65	≤5
Thickness (m)	4 - 20	1-6	0.30 - 8	1.5-2
Width (m)	10s (80% of the deposits between 300 and 400 m)	5-6 (main ribbon body) 150-300 (lateral wings) (90% of the deposits < 250 m)	100s (90% of the deposits ≤ 1 km)	≤5 (Ss bars) 10s (whole sheets including Ss bars) (85% of the deposits ≤ 1 km)
Bedding and sedimentary structures	Bodies divided into storeys up to 10 m wide and 0.6-5 m thick. Parallel lamination very common. Planar cross- and trough-bedding less abundant. Desiccation cracks. Intraclasts.	Parallel and cross lamination dominant. Trough cross-bedding subordinate. Desiccation cracks. Intraclasts.	Horizontal, parallel lamination dominant. Cross-lamination less common. Bioturbation. Desiccation cracks.	Horizontal, parallel lamination very common. Abundant planar cross-bedding. Desiccation cracks.
Architectural elements, lithofacies and geometric relations[1]	CH* (St, Sh, Sl, Se, Ss). Internal erosional surfaces common.	CH** (Sh, Sl, Se). Concave-upward erosional base. Extensive lateral wings.	LS (Sh, Sl, Sp, Sr). Sheet, blanket. Flat, non-erosional or minor erosional bases	DA (Sh, Sp). Bars lying on flat base, with convex upward 3rd order internal and upper bounding surfaces.
Bounding Surface[2]	6th order. Internal 1st to 5th order bounding surfaces	5th order. Internal 1st to 3rd order bounding surfaces	5th order. Internal 1st and 2nd order bounding surfaces.	5th order. Internal 1st to 4th order bounding surfaces.
Interpretation	Deposits of ephemeral braided stream channels initiated by sheetfloods.	Straight to slightly sinuous ephemeral channels accompanied by extensive overbank sheet flooding.	High flow regime sheetflood deposits.	Sheetflood-generated longitudinal bars formed by downstream accretion.

1: *Architectural elements: CH= channel (* and ** used only to differentiate in Fig. 3 between multistorey and ribbon sandstone bodies), LS= laminate sand sheet, DA= lateral accretion deposit (from Miall, 1985). Se, Sh, Sl, Sp, Sr, Ss, St = facies code based on Miall (1978).*

2: *Based on Miall (1985) terminology.*

occurrence of beds with a fining-upwards arrangement of bed thickness and grain size that represents deposition from the initial stages throughout the waning phases of the sheetflood event. Although lateral control over hundred of meters is available, the sandstone sheets cannot be traced into channel sandstone bodies. The majority of sandstone sheets are therefore interpreted as true sheetflood deposits. The intercalated mudstones are interpreted as falling-stage deposits, very low velocity sheetflood deposits, and overbank deposits (Olsen, 1989). The numerous dessication cracks present in the intercalated mudstones indicate that subaerial exposure was common.

Sandstone sheets with sandstone bars (Fig. 3, DA)

This type of sandstone deposit accounts for less than 5% of the observed sandstone bodies. They are very similar to the tabular sandstone sheets described before except that in this case they include in them several isolated or laterally amalgamated sandstone bars. These bars consist of convex-up sandstone mounds resting on horizontal eroded and noneroded surfaces that form part of the tabular sandstone sheets. Individual mounds are up to 5 m wide and 1.5 m thick, perpendicular to the paleoflow direction. Internal sedimentary structures include cross-lamination and parallel lamination (Fig. 4). The set boundaries and laminations are horizontal at the bases of the mounds and arch up towards the tops where they parallel the mound surfaces. The mounds are either covered by mudstone deposits or slightly eroded.

The horizontal bases of the sandstone bars and the association with tabular sandstone sheets seem to indicate that they were deposited by unchannelized flows, probably sheetfloods (Olsen, 1989). The convex up morphology and arching up of internal laminations indicate a depositional origin of the mounds, as opposed to being erosional remnants, although subsequent erosion modified some of the sandstone bars. The sandstone bars resemble some large scale crevasse splay lobes decribed by Tyler and Ethridge (1983) and also braid bars ("sand flats" of Allen, 1983). Because of the lateral amalgamation observed in some of the sandstone bars, the crevasse splay origin does not seem to be very adequate. The sandstone bars probably developed in sheetfloods as small braid bars or longitudinal ridges. Some modern examples of this kind of sand bars were reported in rivers (Coleman, 1969), and intertidal flats (Allen, 1982).

PALEOENVIRONMENTAL CHARACTERIZATION

The association of the four types of sandstone deposits described previously coupled with a predominance of sedimentary structures indicative of upper-flow regime conditions within the sandstone facies of the Quebrada del Cura and Lower Río Jáchal suggest deposition by ephemeral processes. Ephemeral streams occur in arid to semi-arid climates where runoff is sporadic. Modern ephemeral streams and their deposits have been described in different parts of the world (McKee et al., 1967, Picard and High, 1973, Karez, 1972,

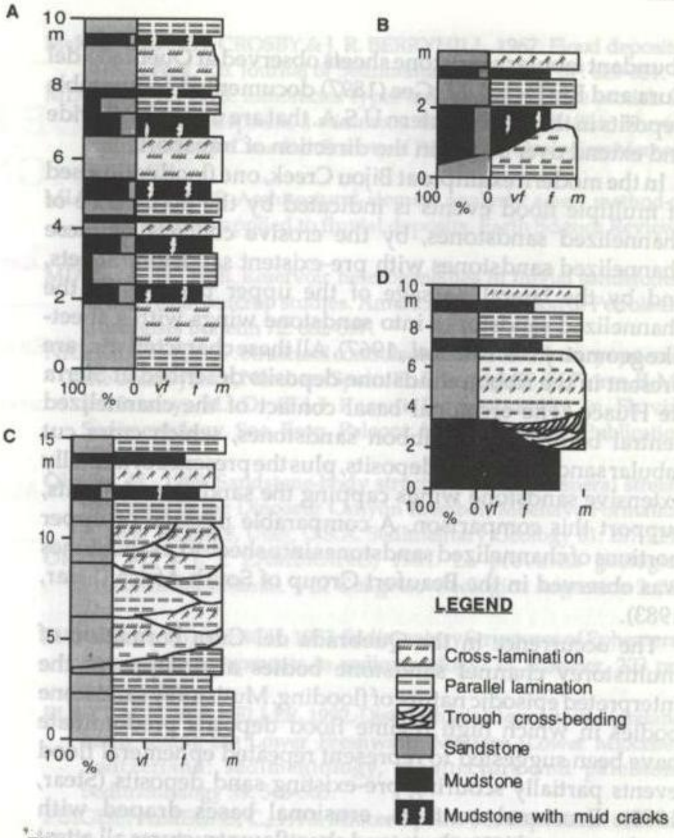

Figure 4: Sedimentological logs showing an example of the four main types of fluvial sandstone deposits recognized in the Quebrada del Cura and lower Río Jáchal Formations. See also Fig.3. (A) Tabular sandstone sheets (LS). (B) Sandstone sheets with sandstone bars (DA). (C) Multistorey channel sandstone bodies (Ch*). (D) Ribbon sandstone bodies (CH**). Grain-size of the sandstone is indicated by *vf* (very fine), *f* (fine), and *m* (medium). Left part of each column shows percent sandstone *vs.* mudstone. Right part of each column shows geometries and sedimentary structures.

and Rust, 1981). Ephemeral stream deposits are characterized by : (1) aggradation rather than lateral accretion; (2) channelized deposits capped by sheetflood deposits or more commonly isolated examples of either; and (3) sedimentary structures indicative of critical to super-critical flow conditions, episodic deposition, and exposure (Deluca and Eriksson, 1989).

The sandstone bodies of the Quebrada del Cura and Lower Río Jáchal Formations resemble modern ephemeral stream deposits described by McKee *et al.* (1967) at Bijou Creek, southwestern U.S.A.. These deposits consist of laterally extensive, tabular sheets of sandstones, horizontally stratified to massive, that were produced by sheetflooding. Subordinate sheetflood facies at Bijou Creek include tabular cross-bedded and trough cross-laminated sandstones, both interpreted as the product of waning flood conditions. Intercalated mudstone deposits produced by late stage aggradation from suspension are present at Bijou Creek as well as in the Sierra de Huaco example. Sedimentary structures in these suspension deposits include horizontal lamination, climbing-ripple lamination, and desiccation cracks. Flood deposits described at Bijou Creek that were produced during a single flood are up to 1 km wide and 1-3.5 m thick, dimensions comparable with the abundant tabular sandstone sheets observed at Quebrada del Cura and Río Jáchal. McGee (1897) documented comparable deposits in the southwestern U.S.A. that are up to 17 km wide and extend over 30 km in the direction of transport.

In the modern example at Bijou Creek, one flood composed of multiple flood events is indicated by the occurrence of channelized sandstones, by the erosive contacts of these channelized sandstones with pre-existent sandstone sheets, and by the lateral passage of the upper portions of the channelized sandstones into sandstone wings with a sheet-like geometry (McKee *et al.*, 1967). All these characteristics are present in the ribbon sandstone deposits described at Sierra de Huaco. The erosional basal contact of the channelized central bodies of the ribbon sandstones, which cross cut tabular sandstone sheet deposits, plus the presence of laterally extensive sandstone wings capping the sandstone deposits, support this comparison. A comparable passage of upper portions of channelized sandstones into sheet-like sandstones was observed in the Beaufort Group of South Africa (Stear, 1983).

The occurrence in the Quebrada del Cura Formation of multistorey channel sandstone bodies also supports the interpreted episodic nature of flooding. Mutistorey sandstone bodies in which high regime flood deposits predominate have been suggested to represent repeated ephemeral flood events partially scouring pre-existing sand deposits (Stear, 1983). Erosional contacts, erosional bases draped with mudstones and intraclasts, and sheetflow structures all attest to an ephemeral stream deposition for the multistorey sandstones in the Quebrada del Cura Formation.

As a whole, the fluvial sandstone deposits within the Quebrada del Cura and Lower Río Jáchal Formations are interpreted to represent sedimentation in a proximal part of an ephemeral-stream sandflat complex. The observed sandstone:mudstone ratio for the Quebrada del Cura and Lower Río Jáchal Formations averages 3:1, but locally sandstones can be up to fifteen times more abundant than mudstones. This characteristic coincides with known proximal sandy ephemeral stream deposits such as those of the Trentishoe Formation of North Devon, U.K. (Tunbridge, 1984).

The proximal part of a sandflat environment is usually characterized by networks of low sinuosity channels carrying a sandy bedload, together with suspended muds, that produce multistorey channel sandstone deposits, like those observed in Sierra de Huaco. The cross-cutting nature of the channels formed in the multistorey sandstone bodies points to repeated episodes of channel cutting, plugging of channels with vertically accreted sandy bedloads, and in turn incision of new ephemeral courses. Such channel behaviour is commonly found in low sinuosity, braided stream systems characteristic of proximal sandflat environments (Tunbridge, 1984). Migrating, low sinuosity, ephemeral braided channel systems may sweep over extensive areas of the upper reach of a sandflat producing sheet sands consisting of sequences of cross-cutting multistorey channel fills (Rust, 1981). As was noted, a major part of the sandstone deposits in the Quebrada del Cura and Lower Río Jáchal Formations also consists of tabular sandstone sheets and ribbon sandstone bodies. While these deposits still record sedimentation in a proximal sandflat they are in a more down-slope setting with respect to the braided channel systems. Here ephemeral channels are less numerous, and shallower, and therefore floods tend to expand into shallow sheets forming laterally extensive tabular sheets of sand. The sandstone sheets sometimes are cut by straight to moderately sinuous isolated channels that are formed during a low stage flow in a multiepisodic flood event (McKee *et al.*, 1967). These isolated channels are then subsequently infilled by sands with horizontal, parallel laminations representative of upper-phase flow forming in this way the ribbon sandstones observed in the Quebrada del Cura and Lower Río Jáchal Formations.

The interpretation of the observed sandstone deposits as being representative of the proximal part of an ephemeral sandflat environment coincides with Beer and Jordan's (1989) interpretation of the lowermost Quebrada del Cura Formation. In this paper the interpretation is extended to the entire Quebrada del Cura and Lower Río Jáchal Formations.

The sedimentological characteristics of the Miocene rocks in the Bermejo Basin suggest that the area was located in a geographic zone with arid climatic conditions. Large volumes of water probably entered the basin intermittently emanating from heavy seasonal precipitation in the Precordillera area or from snow melt in the High Andes located to the west. The drainage system at Quebrada del Cura and early Río Jáchal time consisted of a main high-order trunk stream represented by the ancestral Río Jáchal (Damanti, 1989). This river formed an alluvial fan upon entry into the Bermejo Basin with an ephemeral-stream sandflat environment in the more distal reaches of the fan. The proximal part of this sandflat environment was characterized by a network of ephemeral streams with episodic, short-lived, and violent flooding resulting in a rapid influx of sediments mainly as sheetfloods.

CONCLUSIONS

From the study of Miocene sedimentary rocks of the Quebrada del Cura and Lower Río Jáchal Formations in the Bermejo Basin it is possible to conclude that:

1) The geometry, architecture and sedimentology of the sandstone bodies are characteristic of deposits formed in the proximal part of an ephemeral, arid sandflat environment with flashfloods as the main mechanism for sediment transport and deposition.

2) Four main types of fluvial sandstone deposits can be recognized in the Tertiary section: tabular sandstone sheets, multistorey channel sandstone bodies, ribbon sandstone bodies, and sandstone sheets with sandstone bars.

3) These sandstone bodies are interpreted to represent respectively high flow regime sheetflood deposits, deposits of ephemeral braided stream channels initiated by sheetfloods, low-sinuosity ephemeral channels accompanied by extensive overbank sheet flooding, and sheetflood-generated longitudinal bars.

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