Pliocene vertebrate locality of Çalta, Ankara, Turkey. 1. Sedimentation and lithostratigraphy

Juha Pekka LUNKKA
Department of Geology, University of Helsinki,
P.O. Box 11, FIN-00014 University of Helsinki (Finland)
lunkka@touko.helsinki.fi

John KAPPELMAN
Department of Anthropology, University of Texas at Austin,
Austin, TX 78712-1086 (USA)
jkappelman@mail.utexas.edu

Douglas EKART
Department of Geology and Geophysics, University of Utah,
Salt Lake City, UT 84112 (USA)
ddekart@mines.utah.edu

Sevket SEN
Laboratoire de Paléontologie, URA 12 du CNRS, Muséum national d'Histoire naturelle,
8 rue de Buffon, F-75231 Paris cedex 05 (France)
sen@cimrs1.mnhn.fr

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ABSTRACT
A fossil bearing volcaniclastic sequence at Çalta, Central Anatolia, Turkey was investigated using a modified facies and architectural element analysis. This was done in order to describe the local lithostratigraphy and to shed light on depositional environments and palaeogeography of the area during time of formation. Four main depositional environments were recognized: (1) distal alluvial fan; (2) fluvial channel; (3) overbank and floodplain and (4) pond environment. These environments characterize the evolution of landscape from a relatively steep to land surface of low relief in the more distal part of an alluvial plain. The main fossil beds occur in the floodplain and ponded deposits at levels that show best developed paleosols.

KEY WORDS
lithostratigraphy,
sedimentation,
alluvial facies,
paleosols,
Turkey,
Central Anatolia.

RÉSUMÉ

Le gisement de vertébrés pliocènes de Çalta, Ankara, Turquie. 1. Sédimentation et lithostratigraphie. La séquence sédimentaire des formations fossilifères de Çalta, Anatolie centrale, Turquie, a été étudiée en prenant en compte l'évolution des faciès au cours du temps et en analysant l'architecture des corps sédimentaires. Ce travail a été effectué dans le but de décrire la stratigraphie locale et de mettre en évidence les environnements sédimentaires et la paléogéographie de la région lors de la mise en place de ces dépôts. Quatre principaux faciès sédimentaires ont été identifiés : (1) des coulées détritiques ; (2) des dépôts de chenaux fluviatiles ; (3) des dépôts de plaine d'inondation ; (4) des dépôts marécageux. Les changements de faciès au cours du temps démontrent l'évolution du terrain d'un relief accidenté vers des paysages plutôt plats, dans une partie distale d'une plaine alluviale. Le niveau fossilifère principal se trouve dans des dépôts de plaine d'inondation et d'étangs temporaires ; il correspond également à un paléosol bien développé.

MOTS CLÉS
lithostratigraphie,
sédimentation,
faciès alluvial,
paléosols,
Turquie,
Anatolie centrale.

INTRODUCTION

The small village of Çalta is located approximately 13 km NW of town Kazan in Central Anatolia to the north of Ankara (Fig. 1). The tectonic setting of the Ankara region including the Çalta area has been a part of the collision system involving Eurasian continent to the north, Gondwana to the south and Sakarya continent in between (Sengör & Yilmaz 1981; Koçyigit 1991). Pre-Miocene rocks of the area (Fig. 1) are related to the closure of the Neo-Tethyan Ocean and comprise after Koçyigit (1991) the Karakaya Complex (tectono-sedimentary melange), Ankara Group (marine sedimentary rocks and sedimentary melange), Anatolian Complex (tectonic melange) and the Upper Cretaceous-Middle Eocene Memlik Group that represents forearc basin fill (Fig. 1).

Miocene to Pliocene rocks rest upon Memlik Group with an angular unconformity. These subaerial basalts and volcaniclastic sediments outcrop on the flanks of prominent hills and are covered by recent Pleistocene alluvium in the general region surrounding Kazan and Çalta (Lüttig & Steffens 1976; Lunkka *et al.* 1995; Kappelman *et al.* 1996).

The general lithostratigraphy for the area around Kazan is shown in figure 2. The oldest Miocene sediments exposed in the area are current bedded volcaniclastics that lie beneath the basaltic lava flow dated 15.2 ± 0.3 (Kappelman *et al.* 1996, see Fig. 2). This lava flow is in turn overlain by a thick accumulation of volcaniclastics that become younger from the east, north of Yassiören towards the Çalta area in the west (see Figs 1, 2). These volcaniclastic sediments were deposited in a variety of terrestrial depositional settings ranging from alluvial to lacustrine (Kappelman *et al.* 1996) but have subsequently undergone deformation as a result of neotectonic activity most probably related to the development of the North Anatolian transform fault (Angelier *et al.* 1981; Inci 1991).

The volcaniclastic sediments in the area around the village of Çalta have undergone extensive folding and small anticlinal and synclinal structures dominate the landscape. The fossil-bearing sediments described here occur in tight folded, gently plunging anticline, the axis of which is curved and plunges 15° towards the southwest (Fig. 1). Structural and stratigraphical investigations suggest that the Çalta sedimentary sequence represents the distal part of a depositional system that is related to the evolution of a small, relatively isolated intermontane basin further southwest. Similar relatively small, isolated systems are claimed to be typical for this part of Central Anatolia (Lüttig & Steffens 1976; Erol 1981).

The primary aim of the present article is to present the local lithostratigraphy for the fossil-bearing sediment succession at Çalta and to

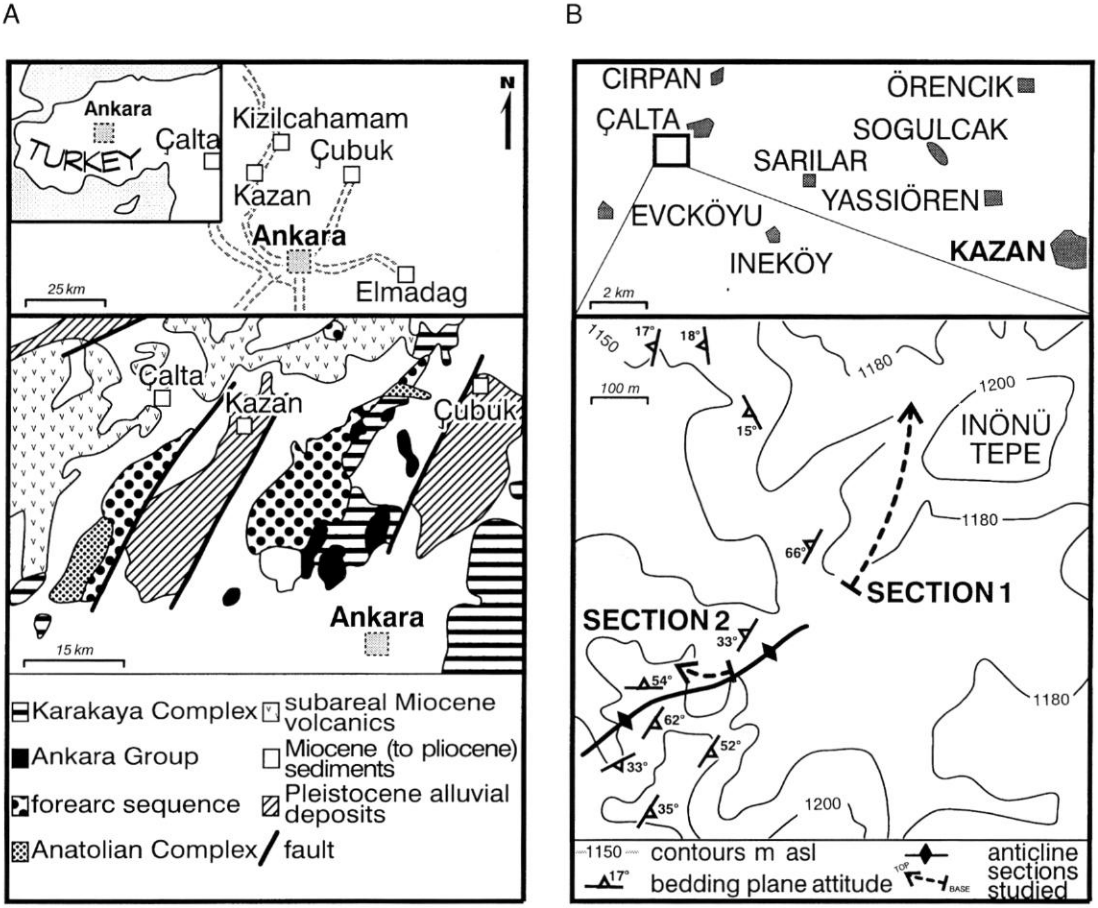


FIG. 1. — **A**, location of the Çalta area near town Kazan and a general geological map of the Ankara area modified after Koçyigit (1991); **B**, location of the study area SW of Çalta and the structural map of the area also indicating Sections 1 and 2 investigated.

reconstruct the paleoenvironments that existed during the time when fossiliferous deposits were laid down.

DESCRIPTION OF LITHOSTARTIGRAPHY AND SEDIMENTS

Two sections were selected for lithostratigraphical and sedimentological investigations at Çalta (Fig. 1). Sedimentary units at these two sites, located approximately 250 m apart, dip between 33°-66° towards the northwest (Fig. 1). Section 1 is 195 m thick while the thickness of Section 2 is 69 m (Fig. 3).

Sediments in both sections are characterized by massive mudstone units that are interbedded with relatively thin layers of gravel conglomerates and sandstones. Pebble-sized clasts studied from conglomerate units have a very consistent composition throughout the sequence dominated by local basalt and siliceous fragments (over 95%) with subordinate amount of sandstone. Although sediments are rather poorly exposed in the area, one continuous conglomerate bed forms a marker horizon that can be traced between

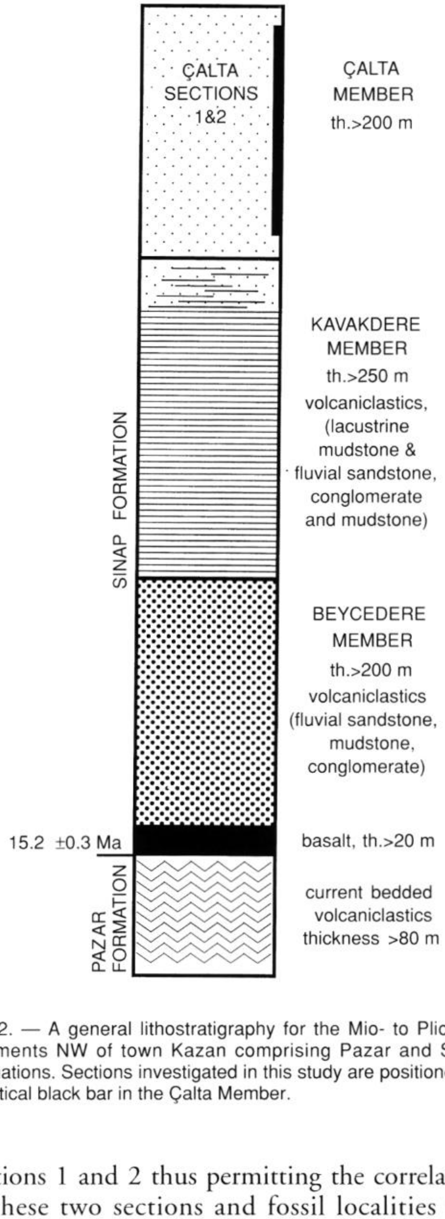


FIG. 2. — A general lithostratigraphy for the Mio- to Pliocene sediments NW of town Kazan comprising Pazar and Sinap Formations. Sections investigated in this study are positioned by a vertical black bar in the Çalta Member.

Sections 1 and 2 thus permitting the correlation of these two sections and fossil localities (see Fig. 3). The main fossil locality, ÇALTA (see Fig. 3) is situated at the 130 m level in Section 1. Two other fossiliferous levels, ÇALTA-2 and ÇALTA-3 are also indicated in figure 3.

A brief description of the various sedimentary facies are given below. The descriptions were made using modified facies and architectural element analysis approaches of Miall (1978, 1985) and Walker (1984).

MATRIX-SUPPORTED, MASSIVE AND DISORGANIZED GRAVEL FACIES (Gms-facies)

Gms-facies occurs in the basal part of Section 1. This facies consists of pebble to cobble gravel conglomerate with a silty clay matrix. The contact between the Gms-units and the underlying mudstone is sharp but non-channelized. Sedimentary structures are absent and oversized clasts are frequent. The lateral extent of this facies is at least several tens of metres although poor exposure prevents a precise definition of the facies geometry and extent.

Mudstone-matrix supported, disorganized and poorly sorted conglomerates are normally interpreted as viscous debris-flow deposits (*cf.* Hubert & Filipov 1989; DeCelles *et al.* 1991). However, it is also possible that thin units of texturally bimodal, pebble to cobble matrix-supported conglomerates that occur in close association with poorly bedded or massive conglomerates (Gm-facies) might have resulted from postdepositional floral or faunal disturbances where larger clasts might have been mixed with fine sediments (DeCelles *et al.* 1987). The Gms-facies is interpreted here as a debris flow deposit although the decimetre thick Gms-units at the base of Section 1 could have also originated from post-depositional disturbances.

MASSIVE OR POORLY-BEDDED GRAVEL (Gm-facies)

The Gm-facies comprises pebble to cobble-size conglomerates with a sand matrix. Pebble gravel conglomerate units are normally less than 1 m thick while cobble gravel conglomerates range up to 2 m in thickness. Conglomerates are almost massive or poorly bedded where clast imbrication is locally present. Individual units may occasionally show grading. The lateral extent of individual sheet-like sediment bodies is at least several tens of metres and the contact between the underlying mudstone is sharp and most probably erosional.

These units show close similarity to Gm-facies described *e.g.* by Todd (1989) and most likely resulted from high density stream flows that carried traction carpets along stream beds. Although most of the Gm-units at Çalta are the products of stream bedload deposits, it is also possible that the thicker units of sand matrix conglomerates

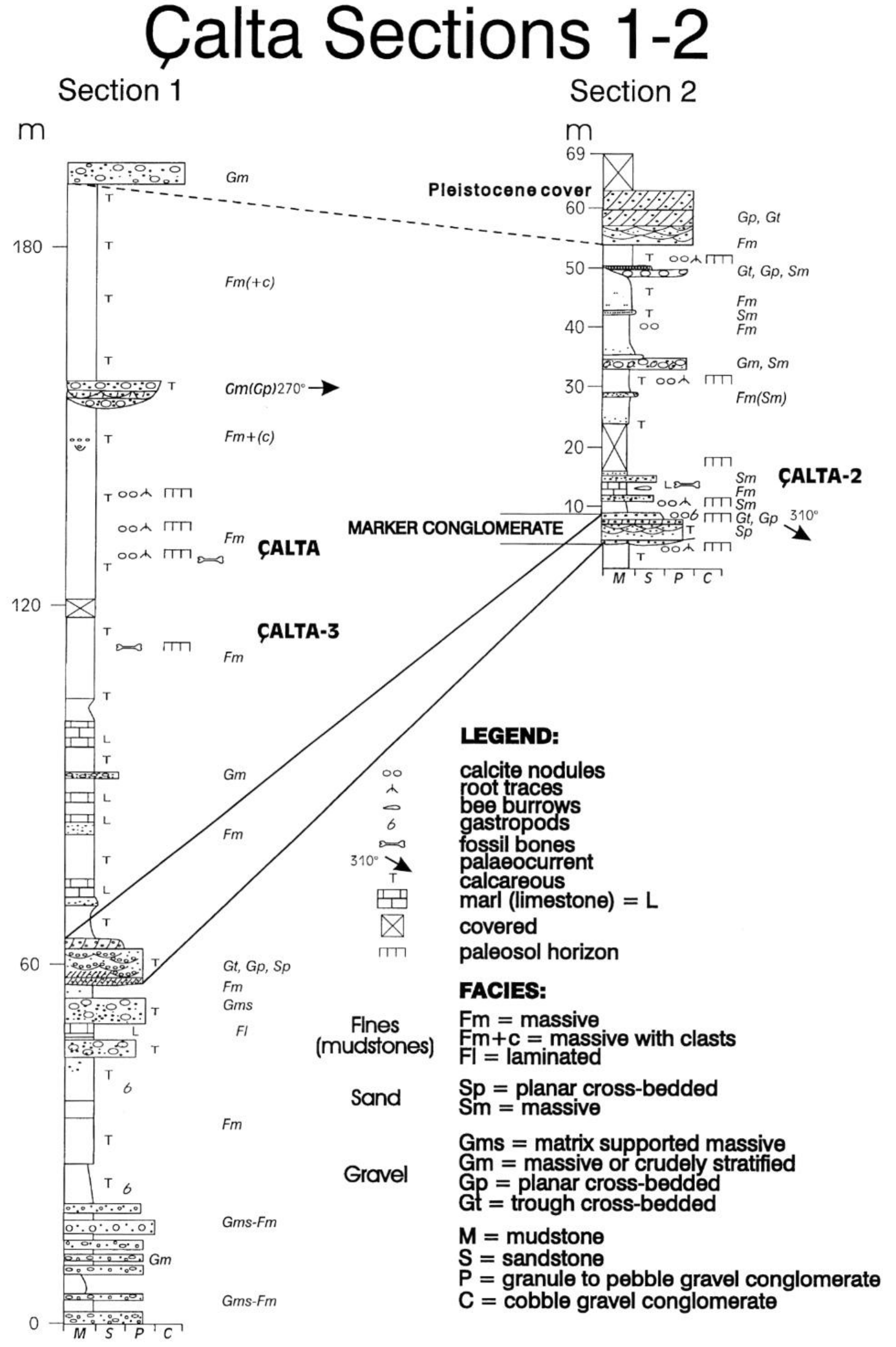
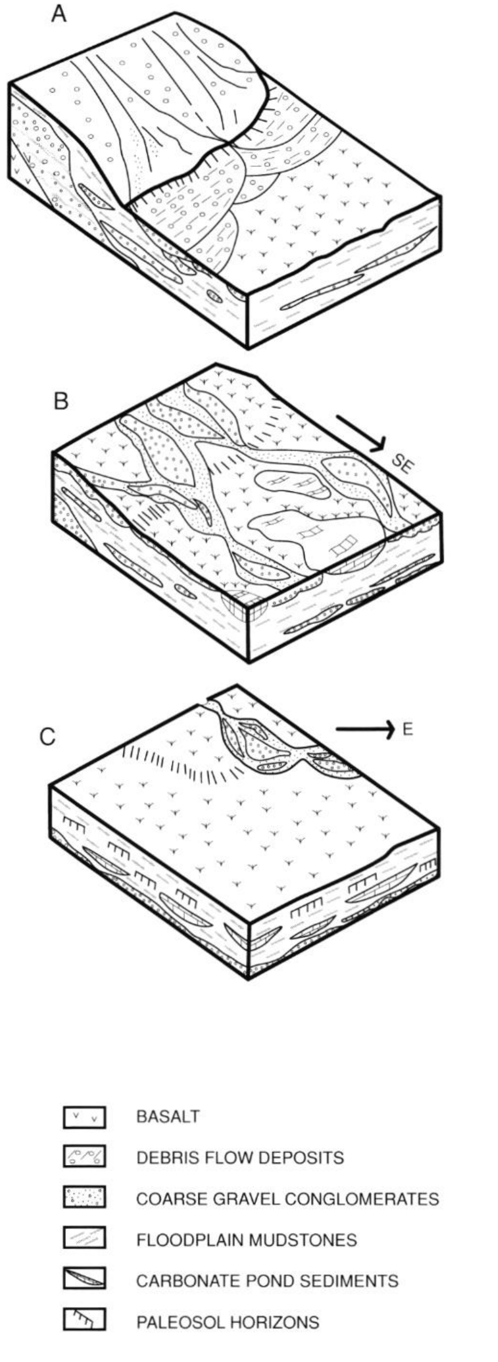


FIG. 3. — Lithostratigraphic logs of Sections 1 and 2 at Çalta. Marker conglomerate and fossil localities together with paleosol horizons are indicated. Arrows indicate palaeoflow directions. Gravel conglomerates at the top of sections are believed to represent modern (Pleistocene ?) cover.



with poor sorting (multimodal grain-size distribution) and the absence of internal stratification were deposited *en masse*.

TROUGH AND PLANAR CROSS-BEDDED GRAVEL AND SAND FACIES (Gt, Gp and Sp-facies)
There are several units of thick (up to 5 m) predominantly trough and planar cross-bedded pebble gravel conglomerate with subordinate amounts of planar cross-bedded sand that occur at the 4-8 m and 57-62 m (Section 1 and 2 marker horizon) levels in the sections (Fig. 3). Gp-Gt facies also occur at the top of the hills in the Çalta area but these beds are considered to represent recent alluvium and are not discussed here.
Cross-bedded gravel conglomerate is laterally continuous for several hundreds of metres, and these units have an erosional lower contact. Laterally and vertically clast-supported gravel bodies pass into stratified pebbly gravel with sand matrix and finally to planar cross-bedded sand. However, the lateral and vertical grain-size changes are abrupt and not systematic. Gravel units are lenticular in cross-section. Palaeoflow indicators (corrected for bedding orientation) show current flow towards the east and southeast.
The Gt-Gp-Sp facies are interpreted to represent fluvial channel deposits including longitudinal bars, side bars and channel fills. This interpretation is based on the lenticular shape of these bodies, their crude upward fining architecture, and the erosional bases of these cross-bedded conglomerates and sands (*e.g.* see criteria used in Miall 1978, 1985; Rust & Koster1984; Mack & Rasmussen 1984; DeCelles *et al.* 1991).

MASSIVE SAND FACIES (Sm-facies)
Massive and, in places, faintly planar cross-bedded, fine to medium sand units that range from

FIG. 4. — Idealized model for sedimentation history at Çalta. **A**, debris flows were generated by infrequent slope wash events when the local land surface gradient was relatively steep (main facies: Gms, Fm, Fl and Gm); **B**, continuously shifting, braided-type channel patterns were developed during and after which shallow water bodies were formed in a relatively flat and stable landscape (main facies: Gt, Gp, Sp, Sm and Fm, L); **C**, Overbank fines continued to accumulate in the floodplain (main facies: Fm and L). These were interrupted by occasional deposition of channel and levee deposits as the distributary channels shifted laterally (main facies: Fm, Gm, Sm).

0.2-1.4 m in thickness are closely related to cross-bedded gravel horizons. These sands normally overlie cross-bedded gravels. Individual sand beds are tabular-shaped bodies and have sharp basal contacts. These bodies are laterally extensive at least for tens of metres. Root traces, burrows, calcite nodules and gastropods were also observed in these sand units.

The tabular geometry and the close relationship with channel deposits along with the abundant evidence for bioturbation suggests that Sm-facies represents reworked sheet-flood and overbank deposits with poor pedogenic alteration (*e.g.* DeCelles *et al.* 1987).

Massive mudstone, siltstone, and marl facies (Fm- and L-facies)

The major part of the sedimentary sequence at Çalta consists of massive, often calcareous mudstones that are slightly silicified in places. A few massive or faintly laminated siltstone beds were also recorded and most of these seem to be related to the marly beds described below. In Section 1 there is one relatively thick accumulation of mudstone including marl beds that occurs above the marker conglomerate (see Fig. 3), while in Section 2 a comparable mudstone is much thinner, perhaps reflecting later erosional events during the Pleistocene. Several thin mudstone units occur between conglomerates in the basal part of Section 1. In addition to these thin mudstones, there is one relatively thick (25 m thick) mudstone unit below the marker conglomerate. The massive mudstones that occur above the marker conglomerate show distinct horizons with typical pedogenic features including mottling, bioturbation, calcite nodules and subparallel calcite veins discussed below.

Based on the massive structure, bioturbation, fossil content, and pedochemical alterations, the mudstones are interpreted here as overbank deposits laid down in a floodplain environment with moderate pedogenic alteration.

In addition to the red brown to light brown and dark grey, often calcareous mudstones, several white marl beds (limestones), 0.9-5 m thick, occur in the sequence. The lower contacts of these marls are somewhat gradational where the underlying massive or laminated siltstone or conglomerate passes gradually into marls. Some of the marl beds show bioturbation in their upper part and pass with sharp contact into massive mudstone or sand. The exact lateral extent of marly horizons is unknown but one of them seems to continue for several hundreds of metres in the sequence. Marl beds are interpreted as remnants of small ephemeral ponds that existed in the flood plain (see *e.g.* Sanz *et al.* 1995).

DEPOSITIONAL ENVIRONMENTS

The facies succession, paleosol horizons, and ponded sediments together with palaeontological evidence (see other contributions in this monograph) clearly indicates that the sediments at Çalta were laid down in a terrestrial setting. As a whole, the sedimentary sequence was most certainly deposited in an alluvial environment. The provenance area is thought to have been local since pebble counts carried out from gravel conglomerate units indicate that the local volcanic rocks dominate the rock assemblage.

In broad terms, the sediments can be grouped into four different categories that characterize the depositional environments during the time when Çalta sequence was deposited.

Debris flow deposits (Gms-facies) alternating with fine sediments are found in the basal part of Section 1. Such flows are generally believed to be generated by steep slopes, loose debris, relatively sparse vegetation cover, infrequent heavy rainfall, and a volcanic terrain with abundant volcaniclastic material (*cf.* Hooke 1967; Wasson 1977; Vessell & Davies 1981). These conditions are most commonly met under arid or semi-arid conditions in an alluvial fan setting (*cf.* Mack & Rasmussen 1984). Since the coarse conglomerate facies in the basal part of the sequence at Çalta does not show features that are typical of a well-developed fan head or mid-fan facies (*e.g.* Walker 1984), the sediment succession in the basal part of Section 1 probably resulted from infrequent slope wash events in the volcanic terrain followed by overbank deposition in the more distal part of an alluvial fan (Fig. 4A). The local gradient of the land surface during this stage must have been relatively steep in order to generate these debris flows.

The cross- or crudely-bedded gravel conglomerate and sand facies represent channel bars that originated from bedload deposition during stream flows. These sediments indicate that during the time when the marker conglomerate (see Fig. 3) and Gp-Gt-Gm-Sm-facies (further up in the sequence) were deposited, a distinct channel configuration was established in the area (Fig. 4B). Categorizing different river types such as straight, meandering, braided or anastomosing on the basis of channel deposits is highly suspect (*cf.* Collinson 1995), but it is well known that coarse-grained bedload streams generally show low sinuosity and moderate or strong braiding. Based on the internal structures observed in gravel conglomerates along with their lateral extent and overall geometry, it is suggested that stream flow deposits at Çalta were laid down by braided-type channel patterns that shifted continuously in space and time across the distal alluvial fan but generally flowed towards the east and southeast.

A fine-grained mudstone facies that includes ponded marls dominates the sedimentary sequence at Çalta and represents flood plain deposits that were modified by pedogenic processes mentioned above. A variety of methods including observations on biogenic features (*e.g.* root traces, terrestrial molluscs, pupal cases of insects, burrows), colour, macro-structures, horizontation and boundaries, granulometrics, micromorphology, and mineral assemblages are normally used to recognize paleosols in terrestrial sequences (*cf.* Retallack 1988; Wright 1989). At Çalta such features including root traces, calcite nodules and veins, slickensides and peds, along with ostracods and pupal cases were almost exclusively observed in the mudstones at distinct horizons (see Fig. 3).

Thin mudstone units that are associated with the debris or streamflow deposits found in the basal part of Section 1 show little indication of paleosol development. These units most probably represent times of more rapid sediment deposition resulting from a higher sedimentation rate during the time when debris flow events were relatively frequent in the area. The thin mudstones were probably buried by subsequent events before pedogenesis could proceed. In the 25 m thick, massive mudstone bed that is found above the basal conglomerates, calcite nodules, calcite layers (*ca.* 2 cm thick), and mottling associated with ostracods occur at 22.5 m and 40.4 m levels (see Fig. 3). These features can be interpreted as pedogenic in origin. However, much clearer paleosol horizons are present in a thick mudstone unit above the marker conglomerate. Two of the fossil beds, ÇALTA and ÇALTA-2, occur in these well-developed paleosol horizons (see Fig. 3).

Relatively thin marl units frequently occur in the middle part of the section (Fig. 3). These marls are interpreted to represent ponded deposits as discussed above. The term pond is considered here as a shallow standing waterbody with reduced extent (see criteria used by Bates & Jackson 1980). In addition, ponds are normally considered ephemeral and lack facies associations typical for other types of standing waterbody deposits such as lakes, playas, salt pans, and marsh deposits (Currey 1990; Sanz *et al.* 1995). The occurrence of pond deposits at Çalta indicates a relatively flat and stable landscape with reduced sediment input. These conditions could have prevailed in a distal flood plain environment when the active channel network (see above) switched out of the immediate area and left isolated, shallow depressions that were occupied by short-lived lakes (Fig. 4B). Overbank fine-grained sediments continued to accumulate in the floodplain environment, and these deposits were occasionally interrupted with channel and levee deposits (Fig. 4C).

The main fossil locality ÇALTA and other mammal fossils found in locality ÇALTA-3 are situated in paleosol horizons while mammal bones at ÇALTA-2 were discovered at the top of ponded sediments and in the higher massive sand unit. Based on taphonomical observations at the site it is evident that all of these bone beds represent more or less *in situ* deposition and each site most certainly represents a contemporary fauna.

CONCLUSION

The lithostratigraphic sedimentary sequence at Çalta comprises four main sedimentary environments that are represented by slope wash, distal floodplain, ephemeral pond and fluvial channel deposits. These facies characterize deposition in an alluvial environment that most probably occurred in a relatively distal part of the drainage basin.

Gravity flow deposits in the basal part of the sequence suggest that the surface gradient was initially relatively steep and slope wash events were frequent across sparsely vegetated hill slopes. A distinct drainage pattern was subsequently established in the area. This second pattern was accompanied by a lowering of the surface gradient to such a degree that a relatively stable and flat landscape was developed. Distributary streams were most probably actively braiding. The abandoned channels created by channel switching formed shallow ponds in the more distal part of the floodplain. This standing water probably served as water holes for the local fauna, and at least one of the three fossil localities (ÇALTA-2) appears to have formed as a consequence of animals dying in the vicinity of the pond.

The presence of relatively well-developed paleosols on flood plain sediments at several horizons in the upper part of the sequence suggests that the sedimentation rate was relatively low. The main fossil locality, ÇALTA, occurs in this depositional setting. Lateral exposure at this level in the section is limited by the steep dip of the beds, but it is hypothesized that a nearby pond in an abandoned channel might have served to attract the animals to the site.

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