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Neogene history of the Tabernas basin (SE Spain) and its Tortonian submarine fan development

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Abstract

The Tabernas Basin is a structural depression in the Alpine nappes of the Betic Cordilleras in southeastern Spain. From the Tortonian to the Plio/Pleistocene, sedimentation in this basin was strongly influenced by tectonic activity.

At the onset of the Tortonian, basin subsidence caused submergence of an alluvial fan system and a small submarine fan complex developed in a water depth of at least 600 m. Total basin subsidence was in the order of 1200 m. Initial Tortonian submarine fan growth and evolution of fan systems has been reconstructed and is shown in 6 palinspastic maps.

In the early Messinian, sediment accumulation on the fan, and basement rise caused a regressive trend. Reefs along the NW margin of the basin were part of a regional barrier reef system and muddy sediments were deposited in its centre.

Prior to the development of an evaporitic phase, uplift and emergence of the eastern half of the basin took place along NW-SE trending faults. During this evaporitic phase, selenitic gymsum formed on the muddy sediments of the still submerged sea floor of the western half of the basin.

At the Messinian-Pliocene boundary, folding and emergence of the sea floor coincided with the genesis of an anticlinorium in the south: this is the now emerged Sierra Alhamilla.

From Pliocene onward, after a short period of subsidence, uplift prevailed contributing to the development of a southward prograding fan delta in the western part of the basin.

The structural and depositional history of the basin seems to agree with its setting within a strike-slip zone. Movement along this zone is associated with the convergence of the African and Iberian lithospheric plates.

Introduction

Structural setting.
Structural development of the Tabernas area has been influenced since early Miocene times by the converging African and Iberian plates (Olivet et al., 1982; Montenat et al., 1987). Convergence is partly accomodated by crustal shear along a strike-slip zone. Two major sinistral strike-slip faults occur near the Tabernas Basin: (1) the Serrata fault (Baena et al., unpubl. comm. 1977) which is elsewhere called the Carboneras fault (Montenat et al., 1987) and (2) the Palomares fault (Bousquet et al., 1975) which is synonymous with the Aiguillon fault (Veeken, 1983) (Fig. 1). The existence of an assumed smaller, sinistral strike-slip fault, the Anda-

rax fault is based on geometrical data only. According to Montenat et al., (1987) the Carboneras and Palomares faults define the present boundary between the Iberian and African plates.

Geological map and lithologies.
The geology was mapped at a scale of 1:25,000 and where required at 1:10,000. Aerial photographs, issued by the Ejercito del Aire, were used in addition. Mapped units represent lithofacies, and are interpreted in terms of depositional mechanisms and environments (Fig. 2. Geological map of the Tabernas area. This map has been inserted in the back of this issue). Facies associations are in the sense of Mutti & Ricci Lucchi (1972) with exception of the lobe fringe and fan fringe associations which are in the sense of Pickering (1983), p. 189: Table 3).

Objectives

The purpose of this paper is (1) to give an analysis of the Neogene sedimentary record of the Tabernas Basin with emphasis on the Tortonian history, (2) to present 6 time-slices illustrating initial submarine fan evolution, and (3) to discuss the tectonic setting of the basin.

Stratigraphy and geohistory analysis

Basement.
Metamorphic rocks of the Nevado Filabride Complex (PM_1) and Alpujarride Complex (PM_2) form the basinal margins and basement for Neogene sediments of the Tabernas Basin (Table 1, Fig. 2). These complexes comprise stacked Alpine nappes and are assigned to the Internal Zone of the Betic Cordilleras (Egeler & Simon, 1969a, b; Vissers, 1981). Nappe stacking largely ended in late Oligocene times according to these authors.

Sedimentary succession.
The Chozas, Turre, Yesares, Abrioja and Gador Formations have been distinguished. All formations have been defined in adjacent basins: Chozas and Turre Formation by Völk & Rondeel (1964); Yesares Formation by Van de Poel (in prep.); Abrioja Formation by Postma (1983); and Gador Formation in this paper. Rock description, sedimentary features, depositional mechanisms and interpretation of sedimentary environments of each formation are summarized in Table 1. Age and areal distribution of the formations are given in Fig. 2. Thickness and lithofacies correlations are presented in Fig. 3. Correlation of the Neogene stratigraphy with adjacent basins is shown in Table 2. Below the structural and depositional framework of the formations are discussed.

Serravallian?-Tortonian-Messinian Chozas Formation

The geohistory diagram (Fig. 4) shows a high rate of subsidence. Contemporaneous synsedimentary deformations (e.g. slumps and slides), as well as the random occurrences of megabeds in late Tortonian to early Messinian strata strongly suggest tectonic activity (Kleverlaan, 1987). The Chozas Formation unconformably overlies the metamorphic rocks of the basin floor.

Depositional framework. Most detritus was shed into the basin from the Sierra de los Filabres in the North as is indicated by 1) sediment composition; detritus consists predominantly of high metamorphic Nevado Filabride rockfragments, 2) palaeocurrent directions measured from clast imbrications in channels, solemarks and cross-bedding in turbidites (in T_7–TM_3 see Fig. 5), 3) basinward fining of grain size: in channels (T_6–T_8) fines from ca 1 m size clasts in the North to sand-size in the South, and 4) the presence of shallow water fauna in the north and deep fauna (ca 600 m) in the south of the basin.

The Sierra de los Filabres formed a pronounced relief from Serravallian times onward as detritus of the Nevado Filabride Complex was not only shed towards the South into the Tabernas Basin (Kleverlaan, 1987) and the western part of the Sorbas Basin (Ruegg, 1964); but also towards the North in the Purchena Basin (Dabrio, 1974), the Albox Ba-

Table 1. Summary of lithologic characteristics and interpretations of depositional mechanisms and sedimentary environments

	CODE	LITHOLOGY	DEPOSITIONAL FEATURES	DOMINANT CLAST SIZE	DEPOSITIONAL MECHANISM	INTERPRETED BASIN FACIES
GADOR FM	Q2	cgl and sst ch,	unidir cl imbr	pebble sd	traction	river deposits
	Q1	cgl and sst ch,	unidir cl imbr	pebbly sd	traction	raised river terraces
	PP1	red cgls and sst ch,	unidir cl imbr, no foss	pebbly sd	traction	alluvial fan
ABRIOJA FM	P5	sd, mudst caliche nodules	unidir cl imbr, calcretic horizons	pebbly sd	traction, diagenesis	palaeosol, floodplain
	P4	matr + cl supp cgls, sst	ch, large scale x-bd, slumpcars	pebbly sd	mass flows	fan-delta foresets
	P3	laminated mudst	fossrich eg.Corbula Gibba,Alpha Venus,plantmatter	mud	hemipelagic	prodelta,interdistributary bay
	P2	matr supp cgl	ang unsorted chaotic v thick bd	boulder cobble	large mass flow	basin margin
	P1	cl supp cgls	well rounded, well sorted	(cobble) pebble	wave reworking	coastal zone
YESARES FM	M4	gypsum, mudst int	(dm's) selenite cristals, no mudcracks, no algae		evaporation	basin centre
TURRE FM	M3	sd amd mudst laminates	very thin beds, parr lam, creep, no foss	v fine sst, mudst	mass flow	basin centre
	M2	cl supp cgl, sst	slumps, bivalves, well rounded clasts	pebbly sd	wave reworked	coastal zone
	M1	limestone reef	locally in situ, predominantly displaced	lorry sized blocks		(eroded) barrier reef
CHOZAS FORMATION	TM3	graded sst mudst undiff	turb intercal in mudst, Ta - Te	sd mud	turbidity currents	outer fan and basin plain
	TM2	graded sst: mudst<4:6	thin bd turbs intercal in mudst Tc -Te	sd mud	lc turbs, hemipelagites	lobe fringe, basin plain
	TM1	graded sst: mudst>4:6	discrete packages thick-thin bd turbs in mudst, amalgam comm, TkU rare	sd mud	lc turbs	lobe (fringe)
	T10	cgl sst mudst triplet	max 60m thick bed, irreg geometry of bed	boulder	coh debris flow + turb	basin-wide seismite
	T9	pebbly sst and mudst	wedging bd, non-normal graded, viscoplastic deformations, closely ass T6, T7		hc turbs	interchannel area
	T8	matr supp cgl, sst	inv + norm graded fills of scour channels nested in mudst cl imbr	pebble	debris flow, hc turbs	mid fan channels
	T7	matr supp cgl, sst	stacked inv-norm graded, masive-laminated thick sst beds		hc turbs	sand-rich lobe
	T6	matr supp cgl, sst	chaoticaly, inv, norm graded stacked cgls	bld	debris flows	feeder channels in thalweg
	T5	blue mudstones	thoroughly bioturbated, vaguely bd, slumping widespread	mud	hemipelagic,dilute massflow	slope and basin mud
	T4	"Porites" limestones	in situ "Porites" reefal limestone amidst cgls of T3			basin margin
	T3	cl + matr supp cgls	subrounded clasts chaotical	boulder to pebbly	reworked mass flows	in near shore depressions
	T2	yellow sst	massive and laminated, non to poorly graded beds, amalgamation common	sst	hc turbs	below wave base, shallow marine
	T1	green matr supp cgl	sdy matrix, non to inv graded, poor cl aligment sheetlike beds, foss	boulder, cobble	debris flows	drowned ST2
	ST3	matr + cl supp cgl	graded sst, calcarenies sub-well rounded cl slump features reef debris	pebble	debris flows, turbs	southern basin margin
	ST2	red cl supp cgl	ch, unidir cl imbric, lateral accretion, sorted, ang	pebble	traction	fluvial int in ST1
	ST1	red matr supp cgl	chaotic non graded, ang, matr coarse pebbly sst	boulder (max 5 m)	non coh debris flow	redeposited scree
	PM2	predominantly phyllites gneisses, quartzites and marbles: Alpujarride complex is mainly exposed South of Tabernas and is basement to the basin				
	PM1	predominantly schists, amphiboltes gneisses and quartzites of the Nevado Filabride complex, mainly exposed North of the Tabernas basin, with exception of ST3 all basinal sediments consist of (redeposited) Nevado Filabride rock fragments				

Key to Table 1

ang:	angular	gr:	graded	mudst:	mudstone
amalg:	amalgamated	hc:	high concentration	sd:	sand
ass:	associated	imbr:	imbrication	sdy:	sandy
bd:	bedded	int:	intercalation	sst:	sandstone
bld:	boulder	inv:	inverse	supp:	supported
cgl(s):	conglomerate(s)	irr:	irregular	$T_{(a...e)}$:	dominant Bouma sequence
cl:	clast	lc:	low concentration	TkU:	thickening upward
ch:	channelised	lam:	laminated	turb(s):	turbidite(s)
coh:	cohesive	matr:	matrix	unidir:	unidirectional
dm:	decimeters	mass:	massive	v:	very
foss:	fossils	max:	maximally	x-bd:	cross bedding

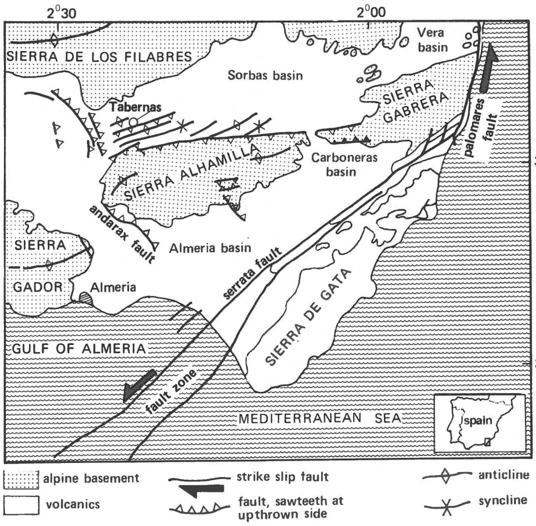

Fig. 1. Structural setting the Tabernas and adjacent basins (modified from data from Platt et al., 1983; Postma, 1983 and Weyermars et al., 1985).

sin and the Huercal Overa Basin (Roep, pers. comm., 1988) and towards the East into the Vera Basin (Völk, 1967).

Evidence for the presence of a minor basement high to the South is yielded by the northward directed transport directions of volumetrically insignificant intercalations of typical low metamorphic Alpujarride detritus (Fig. 6). The northern coastline of the basin contained steep cliffs fringed by coral reefs, which were locally breached by conglomerate-filled depressions (T_2, T_3) and north of the village Tabernas by a major channel complex that fed a small submarine fan system (T_6-TM_3). This system overlies starved basin muds (T_5), shallow marine (ST_3-T_4) and continental coarse detritus (ST_1, ST_2) of a fan delta and alluvial fan. The turbidite succession merges into thin sand and mudstone laminae that are assigned to the Messinian Turre Formation (Table 1) on the basis of faunal content.

(Early) Messinian Turre Formation

The geohistory diagram indicates rapid basement rise for this time period (Fig. 4). There is no folding phase in the Tabernas Basin which is in contrast with the adjacent Sorbas Basin where folding and emergence of the Chozas strata occurred at the Tortonian-Messinian boundary. Uplift along NW-SE trending faults of the area East of road C-3326 (Fig. 2) occurred just before the advent of an eva-

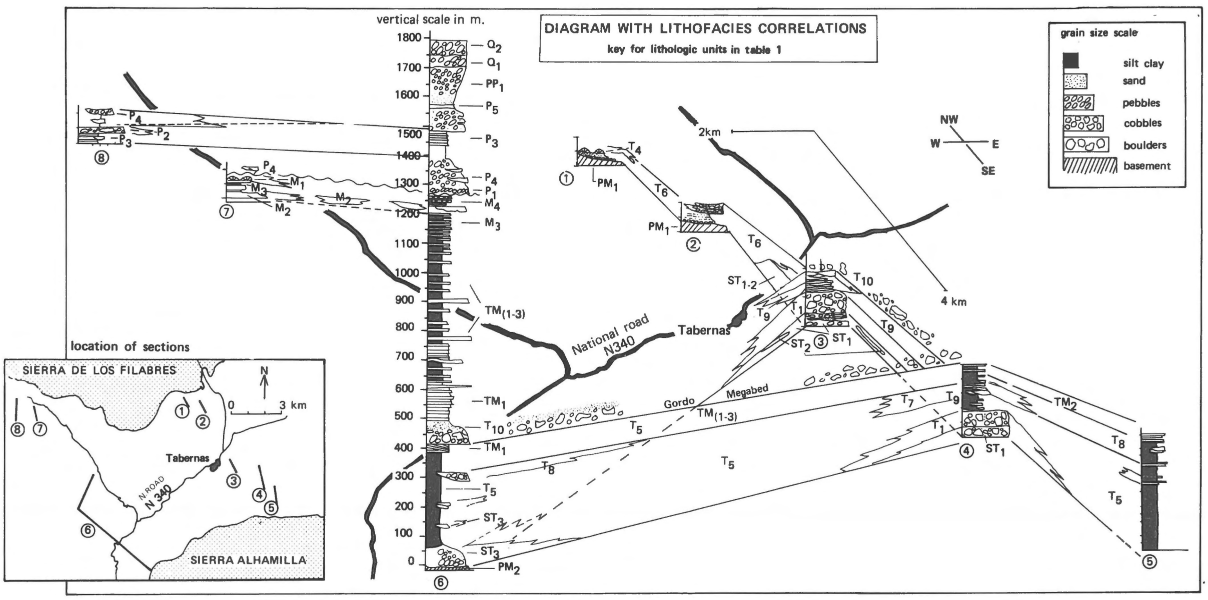

Fig. 3. Diagram with Neogene lithofacies correlations.

poritic phase (Yesares Formation). This uplift is indicated by the presence of conglomerates and slump deposits in an area parallel to the faults and below the gypsum deposits and by the areal distribution of gypsum deposits (Fig. 2). The Turre Formation conformably covers the Chozas Formation.

Depositional framework. Limestone reefs (M_1) and conglomerates (M_2) occur at the northern margin of the Tabernas Basin whereas mudstone laminites (M_3) were deposited in the centre of the basin. The reefs that now occur as isolated erosional remnants were part of a regional barrier reef complex, bordering the Messinian sea (Weijermars et al., 1985; their fig. 2). The multicoloured mudstone laminites represent gravity flow deposits. A line source for this material is suggested by the absence of major channels near the Messinian coastline. Therefore the origin of the laminites may be related to wave activity (e.g. tempestites cf. Aigner & Reineck, 1982).

Messinian Yesares Formation

The geohistory diagram indicates continued basement rise during the Messinian (Fig. 4). The Yesares Formation conformably overlies the marine mudstones (M_3) of the Turre Formation. Reefblocks in a slumped conglomeratic horizon 10 m below the gypsum deposits of the Yesares Formation indicate that reef growth had taken place before the evaporitic phase.

Depositional framework. The Yesares Formation only crops out near the centre of the western part of the basin and consists of selenitic gypsum (M_4) with laminite intercalations. Absence of wave ripples, algal growths or dessication cracks may indicate formation of the selenitic layers below wave base. Similar gypsum deposits in the adjacent Sorbas Basin locally occur below a prograding coastal sequence. In this area the depth of gypsum accumulation has been estimated at 10 to 100 m (Dronkert, 1976; Pagnier, 1977; Beets & Roep, 1978). In general, the Messinian evaporite deposits have been associated with the postulated dessication of the

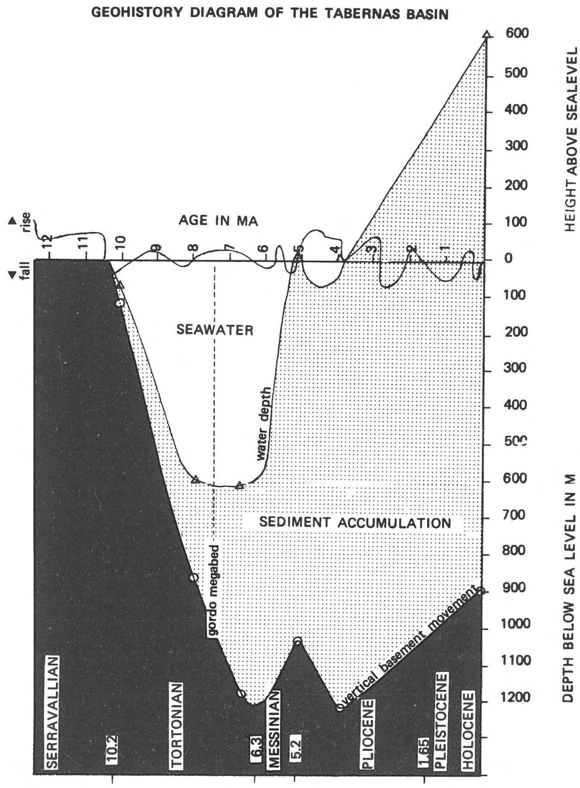

Fig. 4. Geohistory diagram (cf. Van Hinte 1978) of the Tabernas Basin. Time-depth data are based on analysis of planktonic and benthonic foraminifera (J.M. Manuputty written comm.: in Kleverlaan, 1980). The upper and lower curve show the change in water depth and vertical basement movement, respectively. These data are based on sediment thicknesses and faunal data from section 6 (Fig. 2). The strongly undulating line is the eustatic sea level curve from Haq et al. (1987). The diagram illustrates that the transgressive sedimentary series at the onset of the Tortonian may be coeval with a proposed rapid global sea level rise. The increase in water depth, however, is mainly attributed to a high rate of basement subsidence (1200 m). In the Tabernas Basin, the Messinian regression seems largely a response to basement uplift and sediment accumulation. Continued basement rise from the beginning of the Pliocene led to subaerial erosion of emerged marine deposits. This is recorded by an angular unconformity between Pliocene and earlier deposits. The early Pliocene transgression seems to coincide with a global sea level rise. Eventually the rate of sedimentation became higher than the total rate of subsidence and no more marine intercalations were encountered. Basement trends are of course only approximations as emergence and erosion of deposits at the end of the Messinian and from late Pliocene onward introduce inaccuracies.

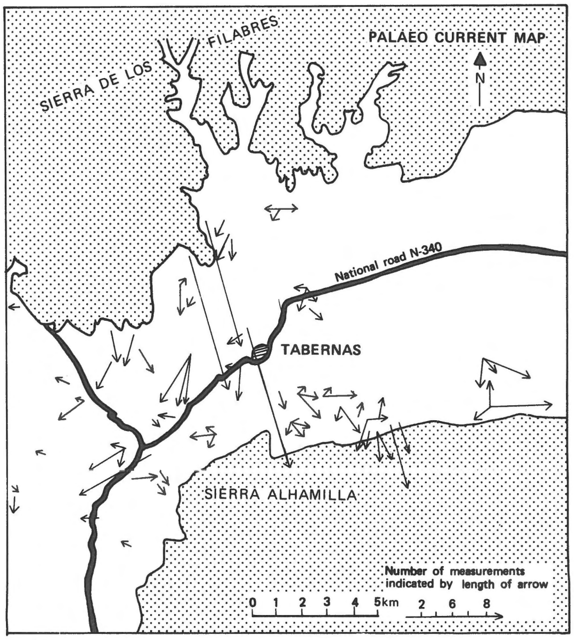

Fig. 5. Palaeocurrents during Tortonian times. Arrows indicate palaeocurrent directions based on solemarks, clast imbrication and T_c crossbedding.

Depositional framework. After the late Messinian-early Pliocene phase of basement uplift and folding, subaerial erosion removed a substantial part of the Messinian sediments and locally exposed and eroded Tortonian deposits (Fig. 1, section III). The angular and erosional unconformity is covered by a transgressive sequence: a basal conglomerate (P_1) that fines upward into marine pebbly mudstones (P_4). These pebbly mudstones locally interfinger with laminated mudstones (P_3). The laminated mudstones are very rich in fossils: foraminiferal assemblages and macro-fossil associations indicate a warm clear sea of maximally 75 m deep (Manuputty, Spaink, written comm. in Kleverlaan, 1980). The sea transgressed from the South through the Rioja corridor into the Tabernas Basin. The Rioja corridor is a structural depression formed by NW-SE trending Pliocene faults (Postma, 1983). A massflow dominated fan delta (P_3, P_4) fed by alluvial fans prograded southward into the Almeria Basin (Postma, 1978). Calcretic paleosols (P_5) prelude the end of marine Pliocene sedimentation.

Mediterranean sea (cf. Hsü, Ryan & Cita, 1973; Van Couvering et al., 1976).

(Early) Pliocene Abrioja Formation

The Tabernas Basin experienced subsidence and subsequent uplift in the early Pliocene (Fig. 4). At the end of the Messinian, folding of Neogene deposits occurred parallel to the anticlinorium of the emerging Sierra Alhamilla. In the area to the East, near Sorbas and Nijar, the Sierra already rose above sea level at the beginning of the Messinian as is indicated by reef growth on metamorphic basement (Weijermars et al., 1985). Thus the locus of deformation moved from East to West. The Abrioja Formation overlies the Chozas, Turre and Yesares formations erosively and unconformably.

*Plio-Pleistocene Gador Formation**

Continued basement rise in the Plio-Pleistocene (Fig. 4) resulted in continental deposits that were contemporaneous with shallow marine deposits of the Abrioja Formation in the Rioja corridor and Almeria Basin. The Gador Formation interfingers and later overlies the Abrioja Formation.

Depositional framework. In the Tabernas Basin sediments of the Gador Formation (PP_1) were deposited in alluvial fans and coastal plains. In the Rioja corridor and southern part of the Almeria Basin fan delta sedimentation occurred while in the eastern part of the Almeria Basin beach conglomerates, reefs and shallow-water muds predominated (Postma, 1978). In the Sorbas Basin, yellow

* No formal definition of the Gador Formation has been published to date, here the Gador Formation is defined as the Plio-Pleistocene continental deposits which have their type locality near the Cerro de la Torre 38.00.11 N and 02.29.40 W i.e. the area 1 km north of the village Gador. These coarse clastic conglomerates and sands erosively cover earlier deposits and are easily recognized by their red colour. They have a large areal distribution in the Tabernas and Almeria basins.

Table 2. Correlation diagram

ALMERIA/TABERNAS Iaccarino et al., 1975	ALMERIA Postma, 1983	TABERNAS This paper	lithology	SORBAS Dronkert, 1976	NIJAR/CARBONERAS Van de Poel, 1989	VERA Volk, 1966
Glacis	Alluvial terraces	Alluvial terraces	sand gravel	Alluvial terraces	Alluvial terraces	Coastal & Alluvial terraces
MORALLA FM	GADOR FM	GADOR FM	brw cgls caliche	GOCHAR FM	CAMPO DE NIJAR FM MOLATA FM	SALMERON FM ESPIRITO FM
	ABRIOJA FM	ABRIOJA FM	soil cgls sands	CANOS FM: Zorreras mb	CUEVAS FM	CUEVAS FM
EVAPORITE FM	TURRE	YESARES FM	selentic gypsum with laminite	CANOS FM: Sorbas mb Yesares mb	FEOS FM YESARES FM calc-arenite & cgl mb	TURRE FM: santiago mb cantera mb
LUCAINENA FM: cantera mb	FM	TURRE FM	inter-calations reefs laminites	TURRE FM: cantera abad azagador	TURRE FM cantera abad azagador	TURRE FM: abad mb azagador mb
LUCAINENA FM: cgl Ra Indalecio cgl	CHOZAS FM	CHOZAS FM	turbidites mudst sandst cgls	CHOZAS FM	SARLADOR FM ?	CHOZAS FM: gatar mb lomo-colorado mb sarlador mb
				MOFAR FM		MOFAR FM
				UMRIA FM		UMBRIA FM

marine conglomeratic sandstones occur intercalated with continental deposits (Roep et al., 1979).

Quaternary

The Plio-Pleistocene sediments in the Tabernas Basin experienced gentle folding along SW-NE directed axes. Two conspicuous levels of river terraces presumably of late Quaternary age post-date the folding phase and are therefore separated from the Gador Formation in the legend of Fig. 2. Q_2 terraces occur at a higher level than Q_1 terraces. The Quaternary deposits have not been studied in detail.

Initial growth of the Tabernas fan complex

Submarine fan sediments of the Tortonian Chozas Formation constitute the bulk of the preserved basinfill (Figs. 2 and 3). Therefore Tortonian history could be studied in much detail and it proved possible to reconstruct horizontal facies development at several stratigraphic levels. This is of importance for comparison with modern fans. Generally, comparative studies have been frustrated by the incongruity of the available data. The wealth of data on horizontal fan development that is typically obtained from research of modern fans is, as a rule, ill-matched by the paucity of similar data yielded by the research of ancient fans. Therefore, the data on horizontal fan development of the Tabernas fan, offer a unique opportunity for future comparative studies. Six time-slices could be reconstructed with the aid of a basin-wide deposit, the Gordo megabed, as datum and several other markerbeds to correlate all available outcrop data (Kleverlaan, 1987; 1989). Accuracy of the reconstruction diminishes with increasing depth below the marker bed, with exception of slice d, at − 30 m, where lateral bed continuity prevails and relatively good correlation of sedimentary units is possible (Kleverlaan, 1989). In spite of these limitations a rather clear image of basin and fan development emerges (Fig. 6).

Time-slices a–f

a) Earliest deposits encountered in the basin are red coloured, very coarse clastic alluvial fan conglomerates (ST_1, Fig. 6) deposited mostly by debris flow and, to a minor amount, by streamflow (ST_2) (cf. Nemec & Steel, 1984). These red conglomerates are absent along the southern border of the basin.

b) Green coloured marine conglomerates (T_1) abruptly overlie the alluvial fan conglomerates. Locally, a more gradual transition is indicated by a (1 to 3 m thick) sandy sequence with intercalations of rounded pebbles. A basin-wide fining upward trend from yellow graded sandstones (T_2) into mica-rich mudstones (T_5) fits the transgressive setting.

c) Conglomeratic channels (T_8) associated with discrete packages of turbidite beds (TM_1) mark the start of submarine fan growth. The sandy lobes (ST_3) at the bottom of the figure are derived from the rapidly drowning southern basin highs. Despite their conspicuous appearance, these sandy lobes only represent a short-lived event: they are not encountered higher up in the sections and they are volumetrically insignificant at 0.012 km^3 (taking exposed width, thickness and inferred length: 6 × 0.002 × 1 km) whereas the total volume of fan deposits is estimated at 150 km^3 (Kleverlaan, 1989).

d) Good lateral control allows a rather detailed reconstruction of the fan surface. Three distinct juxtaposed feeder-lobe systems have been recognised:

   I) a sandy system consisting of a straight thalweg (T_6) terminating in an accumulation of stacked sand-filled scours (T_7);

   II) a muddy system consisting of a straight feeder channel diverging into multiple smaller scour channels (T_8) nested in mudstone. The scour channels terminate in an accumulation of medium to thinly bedded graded sandstones, locally amalgamated and locally with mudstone intercalations (TM_1, TM_2);

   III) a sinuous solitary channel (T_8) extending beyond the depositional areas of the sandy and muddy systems without a significant depositional lobe.

Interaction of initial basin morphology, depositional processes and resultant basin floor relief is believed to have caused an evolution in three different channel-lobe systems. The sandy system formed at the terminus of a pre-existing valley in the basement. After clogging of the feeder system, slope instability led to the development of channels that scoured the muddy depositional slope. The incorporation of eroded slope-muds in down flowing sediment caused a textural inversion and led to the formation of a muddy lobe. In order to explain the narrowness of the solitary system (30 m wide, 25 m deep at 8 km from the palaeocoast) and its extent beyond the lobes of both other systems, an intra-basinal fault escarpment has been postulated (Kleverlaan, 1989).

e) At this stage the sand-rich lobe (T_7) is abandoned and the muddy lobe (TM_3) migrated a little toward the South. Channels are less well defined; they are wider and shallower. They cover larger parts of the slope and are not anymore occupying a particular niche in the slope.

f) A general westward migration of channels combined with a greater extension of fan-lobes took place. Lobe fringe and fan fringe deposits (TM_{1-3}) are well developed.

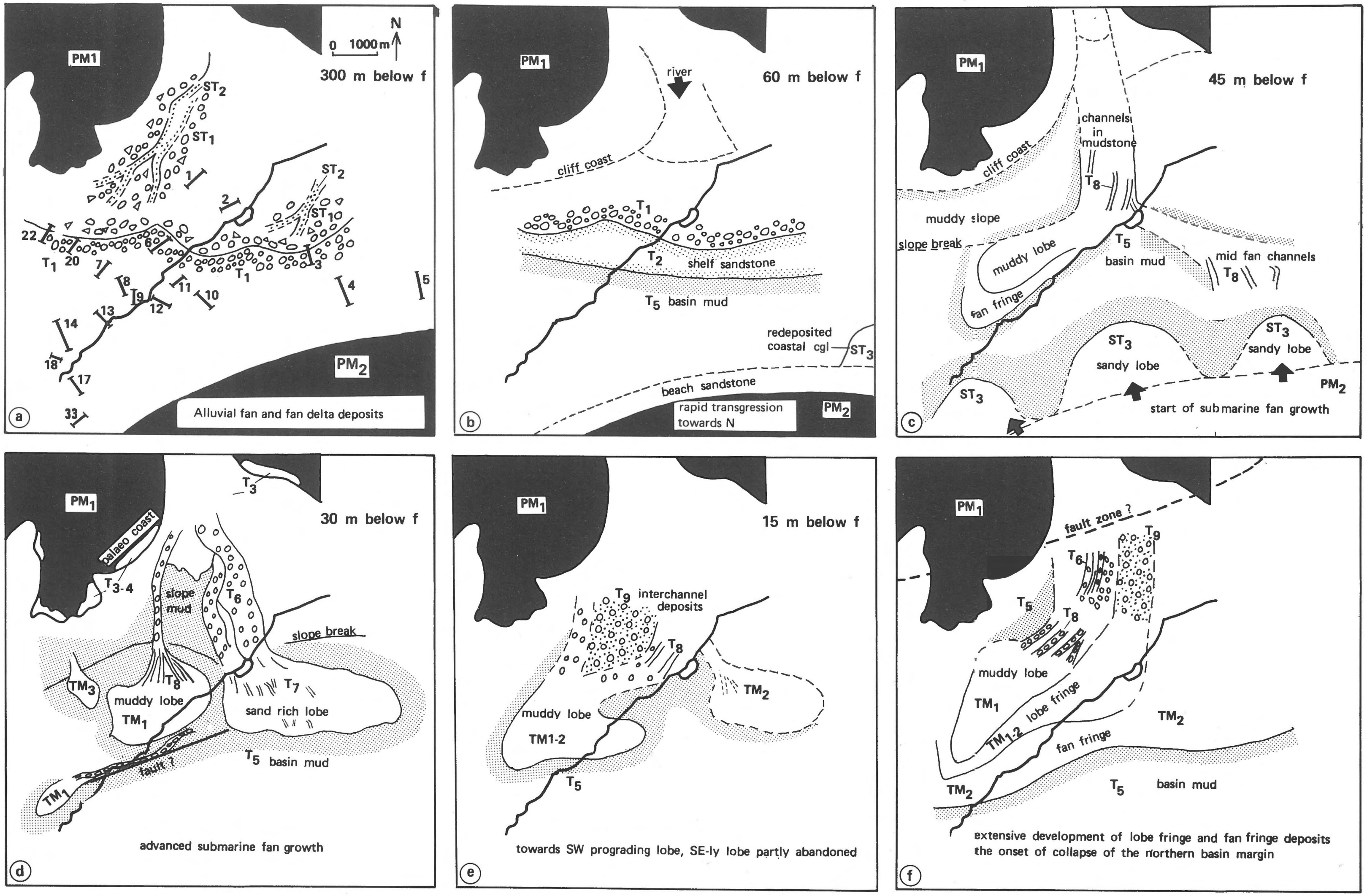

Fig. 6. Reconstruction of 6 stages of horizontal facies distribution in the Tortonian. Maps a and b indicate retreat of coastline and river deposits due to the Tortonian transgression; maps c, d, e and f indicate successively initial stage of submarine fan formation from N to S (c); drowning of land in S and formation and advance of different types of lobes (d); abandonment and lateral shift of fan system (e, f) change of fan growth in a more muddy system. Outlines of the national road N-340, and the best known reconstructed palaeocoast (timeslice 6 d) are given for reference. For further explanation see text.

Rates of sediment accumulation, turbidite frequency and Basin subsidence

Based on sediment thickness between faunal markers, the average rate of sediment accumulation during the 1.3 Ma of late Tortonian fan development is calculated at 0.16 m/1000 yr (Kleverlaan, 1989). If this is correct the evolution shown in Figs. 6 b–f covers approximately 0.3 Ma. The frequency of the turbidites, calculated from the average number of turbidites per measured section, is about 1.5/1000 yr. The maximum rate of subsidence at the beginning of the Tortonian is 1.2 m/1000 yr.

Compared with rates as published by Stow et al. (1985), their figs. 2 and 3, the rate of sediment accumulation and turbidite frequency fan development lies well within the average rates for 'borderland basins' i.e. basins near a transform margin. A shelf was apparently absent during the Tortonian, (Kleverlaan, 1989) thus, sediment was directly deposited from the basin margin onto the fan. Therefore, sediment accumulation in the basin had to be of the same order as the denudation rate of the hinterland. This rate corresponds with denudation of a high relief area in an arid climate (Stow et al., 1985). The total sediment volume is in the order of 250 km^3. This implies that a rock succession of at least 800 m in thickness has been removed from the Sierra Filabres, assuming no significant changes in the location of the watershed of this Sierra.

Discussion

Rates of basin subsidence, sedimentation and turbidite frequency lie well within the ranges for transform basins as compared with compiled date from Stow et al., (1985) and references there in. Differential basement movement of the Sorbas and Tabernas Basins, indicated by the different timing of angular unconformities (Sorbas: Tortonian-Messinian, Tabernas: Messinian-Pliocene) also agrees with the concept of transform behaviour. In addition the short existence of individual depositional systems, the geometry of the basin (12 km long, 800 m deep), the elongation parallel to the major trend of slip, the abundance of mass flows and sediment slides are in accord with criteria for basins in oblique slip zones (Figs. 1, 2 and 5; Table 1) (Link & Osborne, 1978; Reading, 1980; Montenat et al., 1987). However, although not strictly necessary, no visible effects of strike slip offset, such as slickensides, lateral displacement of conspicuous rock successions have been found in the Tabernas Basin to date. Neither does the faulted southern basin border show direct evidence for a strike slip component (Weyermars et al., 1985).

Summary

From the Tortonian onward, a small submarine fan complex evolving from a sandy to a muddy system grew in the rapidly subsiding Tabernas Basin. During the Messinian, basement uplift and sediment accumulation on this fan contributed to a regressive trend. Uplift along NW-SE trending faults caused emergence of the eastern part of the basin. This area was an emerged sill between the Tabernas and the Sorbas Basins from then on. Messinian evaporitic gypsum deposits only occur in the western half of the basin and are probably associated with the Messinian salinity crisis. Folding and emergence of the seafloor at the end of the Messinian coincides with the emergence of the Sierra Alhamilla. In the adjacent Sorbas Basin, the Sierra Alhamillia already emerged at the Tortonian-Messinian boundary. Early Pliocene basement subsidence and ensuing uplift contributed to the development of a fan delta and subsequent onlap of alluvial fan deposits that were gently folded before the deposition of Quaternary river deposits.

Although the tectonic setting of the Tabernas Basin is near a convergent margin and within a transcurrent zone, only circumstantial evidence points to a strike-slip influence on the sedimentary history of the basin.

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