U. S. DEPARTMENT OF THE INTERIOR
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DEPOSITIONAL ENVIRONMENTS AND FACIES IN CONTINUOUS CORE FROM THE SZOMBATHELY-II WELL (0-2150m), KISALFÖLD BASIN, WESTERN HUNGARY

by

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INTRODUCTION

Examination of 2150 m of continuous core from the Szombathely-II well, located in western Hungary in the Kisalföld Basin (Figure 1), identifies six major rock-stratigraphic units, ranging in age from Cretaceous and early Miocene through Pliocene (Carpathian to Upper Pannonian) to Pleistocene. The six rock stratigraphic units in ascending order include: 1) basement schist, 2) nonmarine breccia-conglomerate, 3) regressive marine strata, 4) brackish lacustrine sediments, 5) a deltaic sequence, and 6) nonmarine flood plain strata (Figure 2, sheets 1 and 2).

This well is very significant in that the continuous core allows depositional processes to be identified based on changes in sedimentary structures within vertical sequences; it records sandstone and conglomerate bodies that may form stratigraphic hydrocarbon reservoirs; and it records the environments and continuous sedimentation history of early Miocene through Pliocene (Carpathian through Upper Pannonian) to Holocene strata. Interpretation of the depositional environments especially within the younger Neogene strata, should greatly aid in interpreting and understanding the flood plain environments and deposits within this basin and in adjacent basins in Hungary.

METHODS

The cores were initially investigated by the senior author at the well site at Szombathely and latter at the core depository at the town of Pécs in southwest Hungary. The cores were examined for sedimentary structures, textural changes, and assemblages of depositional sequences from which the depositional environments were interpreted. The cores were initially investigated in detail by staff of the Hungarian Geologic Institute. Paleontologic (foraminifers, ostracodes, mollusks, diatoms, and pollen), magnetostratigraphy, textural, and carbonate investigations established the age and identified the major lithostratigraphic units (Zsolt and others, 1989).

BASEMENT

The stratigraphically lowest unit cored consists of 65 m (2085-2150 m depth) of green schist which represents basement. A Cretaceous age (Zsolt and others, 1989) is indicated for the schist (sheet 2) . Schistosity, which dips from 45 to 50 degrees, is consistent and well-developed throughout the cored interval.

NONMARINE BRECCIA-CONGLOMERATE

Overlying the schist is 161 m (1924-2085 m depth) of interbedded breccia, conglomerate, pebbly sandstone, and sandstone ranging in age from early to middle Miocene (Carpathian to Badenian, Zsolt and others, 1989) (Table 1). The basal strata resting on the schist consists of 21.4 m (2063-2085 m depth) of early Miocene (Carpathian) tan breccia (sheet 2). Angular clasts of schist, quartz, and dolomite as long as 5 cm set within a clast- or matrix-supported texture of pebbly sandstone or only sandstone form the breccia. Schist forms the most abundant clast type. The breccia usually exhibits a disorganized fabric; however, crudely graded to well-graded beds as thick as 10 cm occur between intervals containing a disorganized clast fabric.

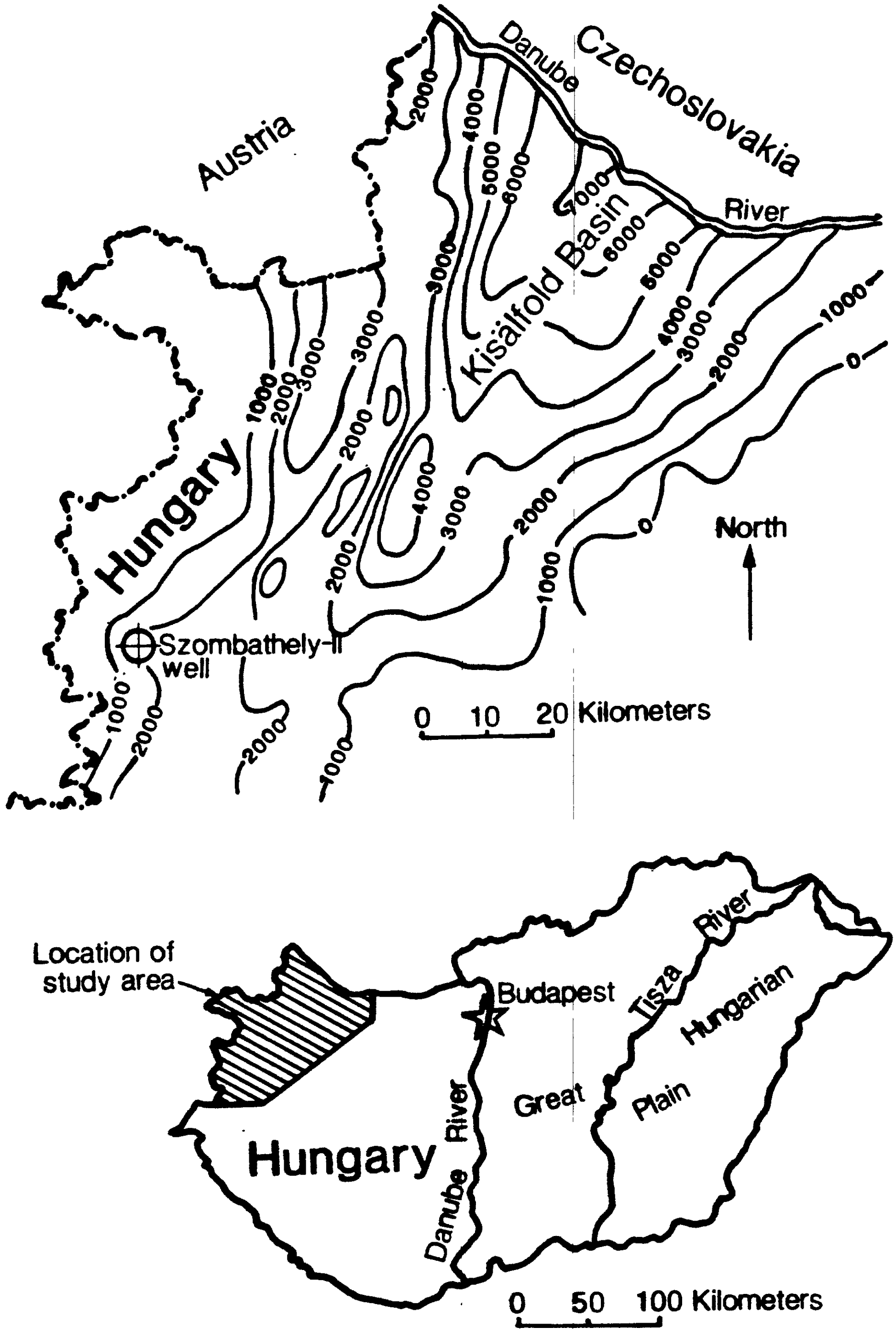

Figure 1. Location of the Szombathely-II well in the western part of the Kisalföld Basin in western Hungary. The isopachs are in meters and represent the Neogene sediment thickness.

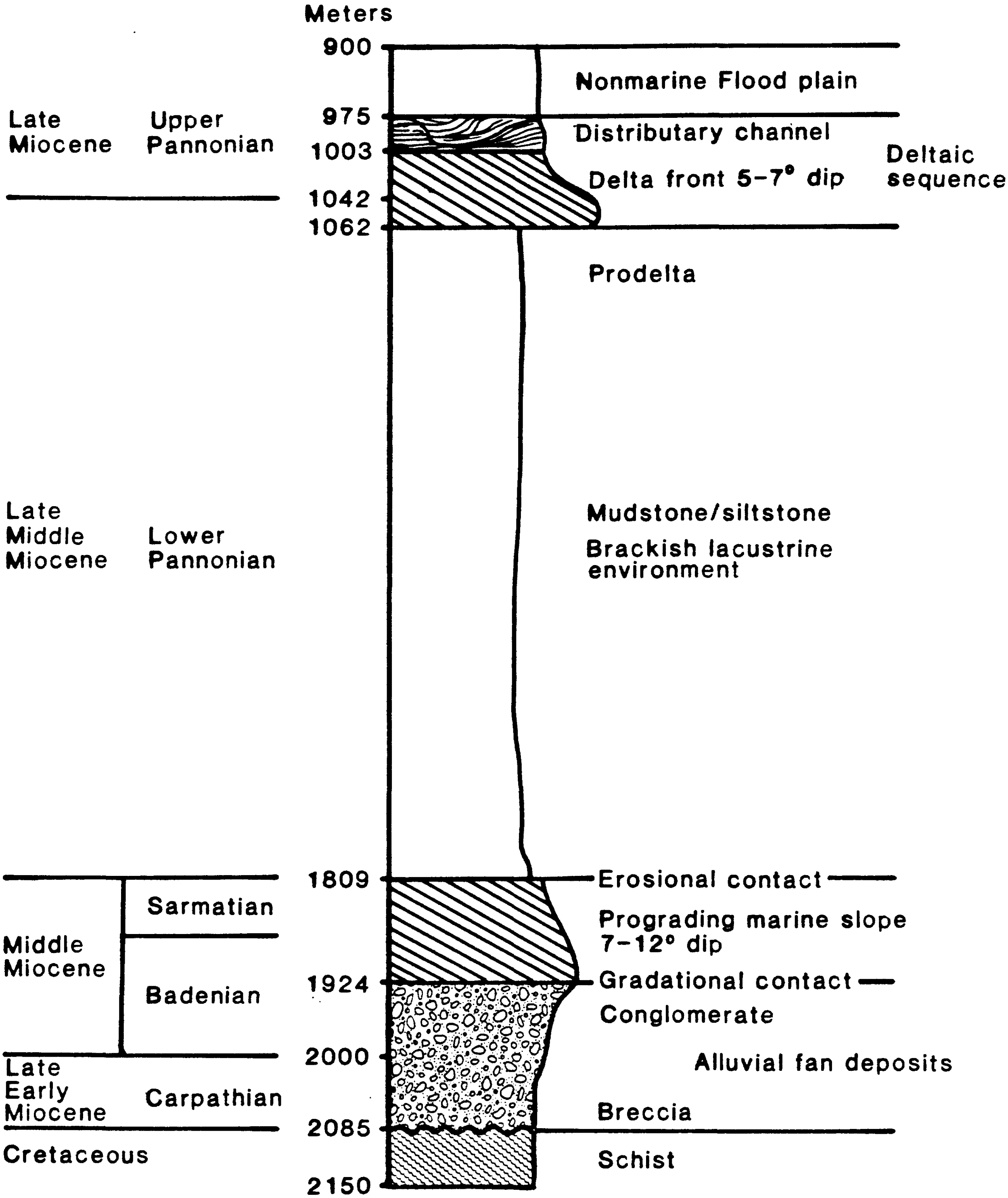

Figure 2. Ages, facies, and rock stratigraphic units below a drilled depth of 900 meters recognized in the Szombathely-II well. (Depths not to scale).

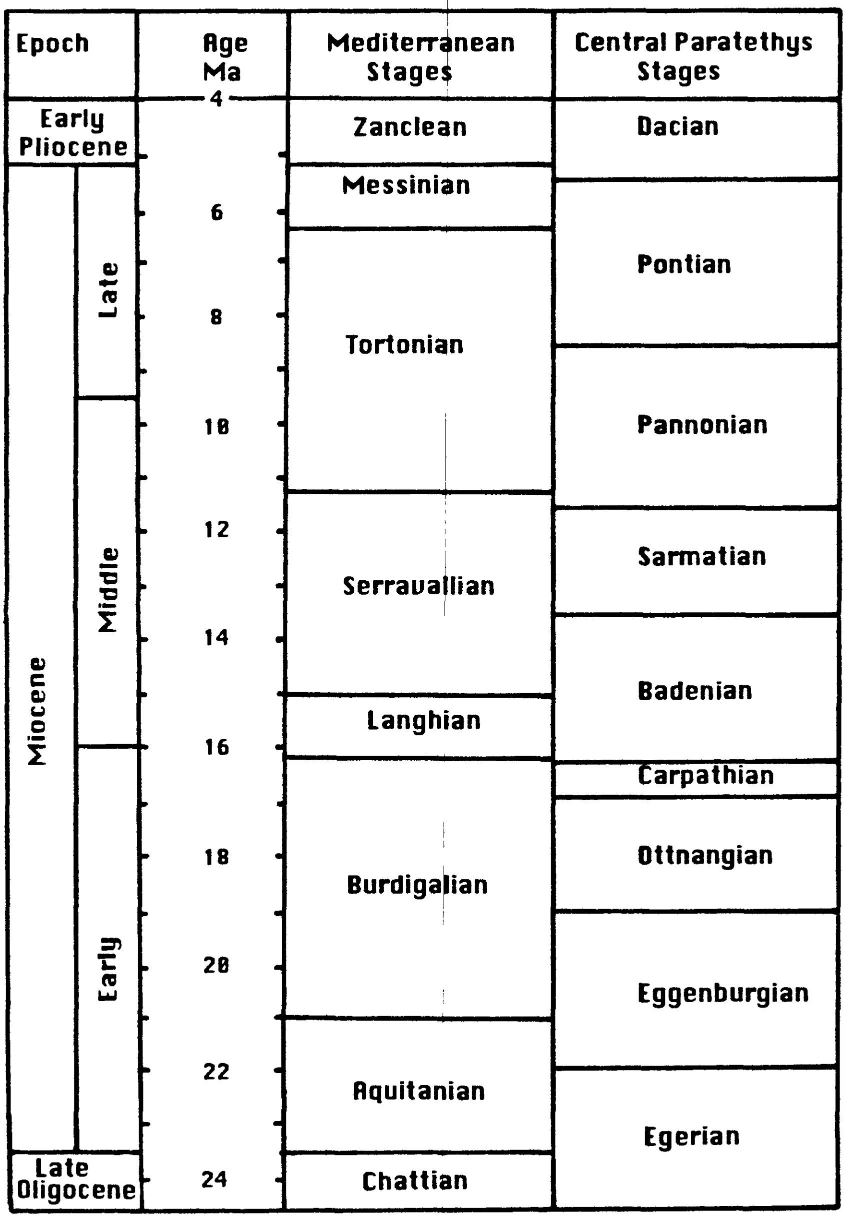

Table 1. Oligocene to Pliocene Central Parathethys and Mediterranean Stages.

Overlying the breccia is 139 m of early to middle Miocene (Carpathian to Badenian) sandstone and conglomerate forming a upward-coarsening sequence (Figure 2). The early Miocene (Carpathian) interval is 70 m thick (1993-2063 m depth). The strata consist of interbedded sandstone, pebbly sandstone, and conglomerate. A three meter thick sandstone bed represents the stratigraphically youngest early Miocene (Carpathian) deposit. Most of the beds within this sequence are thin, ranging up to 40 cm in thickness. The conglomerate and sandstone beds may be graded and in places exhibit large-scale crossbedding. Lignite beds and laminae as well as silt laminae occur within a few of the sandstone beds. The conglomerate clasts are well-rounded and exhibit a clast- to matrix-supported texture. Some beds also have a disorganized fabric.

The middle Miocene (Badenian) conglomerate sequence is 69 m (1924-1993 m depth) thick. The strata consist of massive to very-thick-bedded quartz and schist conglomerate containing a clast- to matrix-supported texture. The schist clasts range in size up to 30 cm and are well-rounded to subangular. Sandstone beds are greatly reduced in number in relation to the underlying early Miocene (Carpathian) strata. In places the clast-supported strata are crudely graded, but elsewhere they exhibit large-scale cross-bedding or inverse grading. The fabric of many of the beds is disorganized.

Interpretation

A subaerial depositional environment, characterized mainly by debris flows (beds with disorganized fabric), and stream deposits (thin crudely graded strata), has been interpreted for the breccia sequences, concurring with the models of Steel and others (1977), Nemec and Steel (1984), and Rust (1979).

The depositional environment of the early to middle Miocene (Carpathian-Badenian) conglomerate sequence is interpreted to be a subaerial alluvial fan deposit. Upsection from the schist the strata exhibit: 1) increasing bed thickness, 2) increasing gravel content, 3) increasing clast size (to boulders), and 4) increasingly more clast-supported disorganized texture. All these features are common to alluvial fan deposits (Nemec and Steel, 1984). Both debris flows (strata containing matrix- to clast-supported disorganized fabric, ungraded beds) and braided stream deposits (strata containing graded beds, large-scale cross-beds, sand and lignite laminations, rounded clasts) are recognized within the conglomerate beds. The sequence of early Miocene (Carpathian) conglomerates, pebbly sandstone, and abundant sandstone beds represents a distal fan toe area (as defined by Steel and others 1977), whereas the upward-coarsening middle Miocene (Badenian) conglomerate represents the middle and upper parts of the alluvial fan. Intermittent braided streams as well as debris flows deposited the sediment forming this conglomeratic upward-coarsening alluvial fan sequence.

PROGRADING MARINE SEDIMENTS

Inclined strata, with primary depositional dips of 7 to 12 degrees (the underlying and overlying strata dip 1 to 2 degrees), form a distinctive prograding marine depositional sequence (Figure 2). The middle Miocene (Badenian to Sarmatian) marine strata are 115 m thick (1809-1924 m depth). A gradational contact containing the initial transgressional depositional sequence (less than a meter thick) exists between the basal non-marine middle Miocene (Badenian) conglomerate sequence and the overlying fossiliferous marine strata. A combination of eustatic sea level rise along with basin subsidence most likely initiated the marine transgression.

The marine strata vary in texture, suggesting variations in past hydraulic energy conditions and sediment supply during deposition. The basal 20 m of strata (1904-1924 m depth) consists of quartz conglomerate in graded beds, wherein many beds are amalgamated, or these beds are interbedded with thin laminated sandstones. Conglomerate, in graded beds (Bouma Ta, Tab sequences) is also found higher in the section between the 1831 to 1849 m depth interval (sheet 2). Alternating mudstone and sandstone laminae and thin sandstone beds are the most abundant depositional features in the sequence. The upper 20 m of the section also contains alternating mudstone and sandstone laminae, and occasionally, thin sandstone beds that may represent a upward-fining sequence at the top of this depositional cycle. Graded sandstone beds, as thick as 146 cm, and displaying Ta-Tab sequences, together with amalgamated sandstone beds that alternate with thin mudstone laminae, form thick repetitious sequences in this marine unit.

Sedimentary structures indicative of down-slope sediment transport are present. These included inclined, graded turbidite sandstones with sharp basal contacts, graded sandstone beds with load structures denoting a regime of rapid sedimentation, down-dip-oriented deformation features (slumps), truncated laminae, and unidirectional down-dip-oriented small-scale cross-beds.

Abundant marine foraminifers, bryozoans, ostracodes, and one occurrence of transported rhodolites (algal nodules) document a marine environment for this deposit.

Interpretation

The inclined strata represent a prograding marine slope. The minimum water depth, as indicated by the thickness of the sequence, is estimated to be 115 m, however, water depths are expected to be greater for the marine sequence. The absence of gently inclined shelf deposits or marine topset beds overlying the slope deposits suggests erosion of the shallow marine shelf sediments. Erosion related to a falling sea level formed this regressive sequence.

Processes that deposited sediment on the slope include density underflow currents which produced the laminated mudstone and sandstone laminae, down-slope currents as indicated by the unidirectional down-dip-oriented small-scale crossbeds, turbidity currents forming graded and amalgamated sandstone and conglomerate beds, and gravity flows causing occasional slumping of the strata.

The prograding nature of this unit suggests that a shallow shelf environment (an erosional shelf of a shallow, high-energy environment) was present, or alternately, a narrow shelf with abundant fluvial sediment influx. The occurrence of gravels within this sequence argues for the latter. The preserved deposit represents shelf margin deposition that occurred during a falling sea level. The sequence contains a thin depositional basal unit overlain by inclined (prograding) strata and an eroded upper (toplap) surface all of which are features common to progradational regressive deposits as observed in regressive Tyrrhenian Sea shelf margin deposits (Trincardi and Field, 1990).

LACUSTRINE SEDIMENTS

Late middle Miocene (lower Pannonian) lacustrine sediments form a 747 m thick sequence (1062-1809 m depth) consisting mainly of mudstones. Sandstones and conglomerates comprise only a small part of this sequence, including a basal sandstone-conglomerate unit, four turbidite sandstone sequences separated by mudstone, and two occurrences of basinal channel-fan deposits. The sequence represents deposition in a deepening brackish-water environment; the lowest beds record sedimentation in a high-energy environment, followed by quiet-water deposition, then prodelta shallow lake deposition.

The lacustrine strata are separated from the underlying marine beds by an erosional contact. An abrupt change in texture up-section from conglomerate to siltstone-claystone, a change in bedding orientation from marine slope deposits dipping at 8 degrees to essentially flat lying beds, and a change from marine to brackish fauna characterizes the change from marine to lacustrine environments.

The basal lacustrine strata consist of 23 m of horizontal bedded, amalgamated sandstone and conglomerate (1786-1809 m depth). The strata consist of graded sandstone and conglomerate (Ta,Tab Bouma sequences) in beds as thick as 47 cm. Laminated mudstone is interbedded with the coarse sandstone-conglomerate beds.

The conglomerate is composed of rounded to well-rounded quartz and schist clasts. The clasts are as large as 4 cm in the basal beds and their size decreases upward. Laminations rich in lignite are present in these basal beds, many of which have been subjected to bioturbation.

Mixed marine and brackish-water fauna characterize the basal beds, changing to a brackish-water fauna within a few meters up-section. The marine fauna was reworked from the underlying marine strata.

Sand bodies, at depth intervals of 1764 to 1775 m, 1754 to 1759 m, 1716 to 1720 m and 1711 to 1712 m, record episodic coarse clastic influx into the basin. The sandstone beds are graded (Ta-Tab sequences) and have an irregular base produced by either erosion or sediment loading. The strata occur as amalgamated beds or as solitary beds interbedded with mudstone. The beds also exhibit deformation, flame structures, and contain rip-up clasts, shell debris, and gravel (clasts to 2 cm).

Massive to rare laminated mudstone forms a 649 meter thick stratigraphic section above the basal coarse clastic beds. The mudstone is locally bioturbated and contains thin pelecypod shell beds or scattered pelecypods.

Interbedded with the mudstone sequence are two depositional units that may record channel-fan deposition based on the vertical assemblage of sedimentary structures. The stratigraphic lowest sequence between 1310 to 1334 m consists of 23 m of laminated mudstone dipping at 8 degrees (sheet 2). This overlies a 1-meter thick bed of horizontally laminated siltstone and sandstone. The inclined strata represent the lateral migration of a basin floor channel accretionary bank. The thin sand unit in the channel base suggests that sand may have by-passed this area and moved downslope into the deeper parts of the basin.

Another sand body, in the 1199 to 1211 m interval consists of a 12 m thick sequence (sheet 2) of small-scale crossbedded sandstone interbedded with silt laminations containing lignite. The upper part of this sequence consists of three upward-coarsening sandstone beds containing unidirectional small-scale crossbeds. This entire fine-grained sandstone sequence is interpreted as a basin floor channel or fan deposit. The absence of inclined strata (formed by lateral migration of a channel bank) suggests that, this sandy sequence is a basin floor channel-fan deposit, constructed by shallow channels. Sediment was transported as small-scale bedforms in a low energy flow regime.

Interpretation

The transition from a marine environment to a brackish lacustrine environment is abrupt and because of the erosional interval present at 1809 m depth, the stratigraphic history is difficult to reconstruct. The initially deposited coarse-grained clastic sediments represent processes operating in either a high-energy (wave-dominated) shallow-water environment or processes associated with turbidity currents. In either case the water depth must have been shallow at this site, and fluvial sediment sources must have been proximal enough to supply the coarse clastic sediment present here.

As water deepened fine-grained sedimentation (silt and clay) was initiated. An influx of clastics resulted in deposition of four turbidite sand bodies. The successive bodies record a decreasing trend in the number of beds in each depositional unit. At the position of this well, a broad paleo-valley apparently exists and this depression may have served to funnel the coarse-clastic sediments into the basal lacustrine deposits. Tectonic uplift could also have increased fluvial sediment discharge into the basin.

The lacustrine sedimentation is dominated by deposition of fine-grained sediment. The Szombathely-II core does not contain the expected characteristic laminated lacustrine strata. This suggests that seasonal turnover of the lake, which produces characteristic seasonal laminations, may not have occurred or that the laminae were not preserved. The lake may have been shallow and well-mixed, a clue for which is the apparent low organic content of the sediment. Alternately, extensive bioturbation may have destroyed the laminae resulting in the massive or structureless appearance of the mudstone.

Channels, such as the solitary channel-accretionary bank and channel-fan deposits existed in the lake floor and likely transported sediment to deeper parts of the basin.

DELTAIC DEPOSITS

The brackish lacustrine environment is superseded by progradation of a delta into the shallow lake (sheet 1 and 2). Three facies of the prograding delta are recognized in the core; the prodelta-lacustrine basin floor sequence, a delta front sequence, and a distributary channel deposit. The strata transgress the late to late middle Miocene (Lower-Upper Pannonian) chronostratigraphic boundary (Zsolt and others, 1989), with the age transition occurring in the delta front deposits.

Prodelta sediments (below 1062 m depth) consist of massive-bedded lacustrine mudstone and rare thin-bedded graded turbidite sandstones. The delta front deposits comprise a 59 m thick sequence (1003 to 1062 m depth) of inclined strata dipping 5 to 7 degrees. The inclined strata consists of interbedded sandstones, siltstones, and claystones, wherein sand beds are as thick as 20 cm. Features observed in the deposit include abundant graded siltstone (Ta sequences), lignite laminae, alternating sandstone and siltstone laminae, down-slope-oriented sets of small-scale crossbeds, graded sandstone beds some with rip-up clasts, deformed (slumped) to overturned beds, and bioturbated claystone. The basal part of the delta front deposits consists of inclined and interbedded laminated mudstones and thin sandstone beds.

Eroded into the inclined delta front sediments is a deltaic distributary channel deposit. The distributary sequence is 28 m thick (975 to 1003 m depth) consisting of planar-bedded and crossbedded sandstones and siltstones. The 3-m-thick basal channel deposit consists of horizontally laminated lignite interbedded with sets of unidirectional small-scale crossbeds. Large-scale sets of crossbeds, to 50 cm thick, alternating with sets of small-scale crossbeds and silt laminae overlies the lignite bed and forms the basal channel-fill sequence. The large-scale crossbeds change up-core to sets of small-scale crossbeds and lignite laminae in the upper part of the channel-fill deposit.

The channel-fill deposit is overlain by a 1.5 m thick laminated and cemented calcareous claystone bed, which in turn, is overlain by 7.7 m of interbedded laminated siltstone, lignite laminations, and sets of small-scale crossbeds. A thin distributary channel deposit (955-960 meters depth) tops the laminated and crossbedded sandstone and siltstone sequence.

Interpretation

This fluvial-deltaic depositional sequence represents sediment progradation into a shallow lake. The minimum lake depth is estimated to be 87 m as determined from the distance between the top of the distributary channel and the base of the delta slope, and the maximum depth 108 m as determined from the distance between the top of the laminated lake sediments at 960 m depth and the base of the slope (depths probably would be greater as sediment compaction has not been determined). The distributary channel supplied sandy sediment to the delta front; however, the channel may have extended down-slope as far as the prodelta basin floor. This interpretation is suggested by the rare occurrence of turbidite sands in the prodelta facies.

Sedimentary processes on the delta front included density underflows that produced the abundant sand-silt-clay laminations, down-slope currents indicated by sets of down-dip-oriented small-scale crossbeds, slumping of beds, and turbidity density currents indicated by the graded sandstone beds.

The thin lacustrine deposits overlying the fluvial distributary sequence grade upward to a marsh deposit and record lake margin and flood plain deposition.

FLOOD PLAIN

The flood plain sediments consist of 960 m of late Miocene and Pliocene (Upper Pannonian) to Pleistocene nonmarine strata (sheet 1). These deposits represent a variety of paleo-environments, including stream, lakes, ponds, marshes, and flood plain. The sequence consists of interbedded sandstone, siltstone, claystone, and lignite beds.

Fluvial distributaries

Fluvial distributary deposits contain most of the sand-size sediment within the flood plain depositional sequence. These deposits consist of upward-fining units that range in thickness from 1.2 to 19 m. The fluvial beds change in texture from sand near the base to silt to clay near the top of the depositional sequence, with the uppermost beds usually containing root structures. Distinctive, inclined accretionary bank strata (point bars) are present in approximately 25 percent of the channel-fill deposits. The channel deposits can be solitary, or interbedded with marsh or overbank beds, or can form vertically stacked multistoried channel depositional sequences.

Sedimentary structures in the channel deposits vary greatly. They range from large- to small-scale crossbeds, or may consist only of small-scale crossbeds, contain abundant lignite laminae or planar laminae of sand and silt, and contain epsilon cross-strata (accretionary bank strata). The accretionary bank deposits are inclined strata dipping 10 to 20 degrees, composed of alternating small-scale crossbeds and laminated sand and silt forming distinctive deposits ranging from 1.2 to 10 m in thickness.

Flood plain lake deposits

Shallow lake deposits occur interbedded with the flood plain sediments. The lake sediments consist of bioturbated to structureless beds of limestone, dolomite, or mudstone containing pelecypods and gastropods. The shallow lacustrine depositional sequences range from 4 to at nearly 40 m of section. The thickest lacustrine deposits (core interval 930 to 887 m) represents either a shallow lake environment on the flood plain, or deposition consequent to a rise in the Upper Pannonian lake level. The depositional sequence from the basal deposits start with lignite beds (marsh) which are overlain by laminated silt and three upward-fining and upward-thickening sandstone beds. Small-scale crossbeds and planar laminations form a prograding sequence. Bioturbated limestone and silty claystone, 12 m thick (904 to 916 m), containing scattered shells represents the shallow lake deposit. Small-scale crossbeds of sandstone, bioturbated and laminated siltstone, an upward-coarsening sequence from claystone to sandstone, that contains small-scale crossbeds, represent the final stage of lake sedimentation and progradation of the adjacent flood plain sediments into the the shallow lake.

Ponds-marshes

Shallow ponds and marsh environments were also present on the flood-plain. The pond deposits consist of thin beds of bioturbated limestones and dolomites, interbedded with bioturbated claystone, siltstone, and thin lignite beds or laminations. Fresh-water mollusks, abundant root structures, and plant debris (reeds) have been incorporated into these sediments. Fining- and coarsening-upward sandstone beds overlying the pond and marsh depositional sequences formed by progradation and lateral filling of the flood plain marshes and ponds.

Flood plain

Flood plain sediments consist of upward-fining and -coarsening deposits. The texture of the flood plain sediments is usually very fine silts and clays, interbedded with the coarser grained fluvial deposited sands. Overbank deposits directly related to the fluvial sequence are recognized as thin upward-coarsening sand and silt beds and laminae, that overlie the fluvial deposits (many upward-coarsening beds represent crevasse splays prograding onto the adjacent flood plain or depending on the vertical stratigraphic sequence also represent stream deposits prograding into shallow lakes, ponds, or marshes on the flood plain). Strata containing lignite beds and laminae, mottled clay and siltstone containing blocky structure, calcareous nodules, as well as locally preserved root structures represent paleosoils within the flood plain deposits.

Interpretation

Flood plain sedimentation was dominated by fluvial systems. The channel deposits allow the reconstruction of the river systems as a function of the geometry of the sand bodies produced by them. Accordingly the largest channel was at least 19 m deep and perhaps as wide as up to 650 m (width determined by the method of Leeder, 1973), which dimensions signify that a major distributary crossed the flood plain. Streams, as shallow as 1.2 m deep and at least 7 m wide, form the smallest fluvial tributary observed within this sequence. A wide range in river-stream size can be deduced from the numerous upward-fining sand deposits in this sequence (sheet 1). Both multistoried and solitary channel deposits characterize this flood plain. The rivers and streams were low-energy systems as most channels are filled with lower-flow regime small-scale sandy bedforms. Other channels, in which large-scale crossbeds were built had higher velocities, although still in the lower flow regime. The rivers meandered on a gently inclined flood plain. The flood plain also contained shallow lakes, ponds, and marshes with extensive overbank sedimentation depositing the silts and clays.

CONCLUSIONS

Examination of continuous core from the Szombathely-II well in the southwestern part of the Kisalföld basin identifies six rock-stratigraphic units. In ascending order, these units consist of basement schist, a nonmarine breccia-conglomerate fan deposit, a prograding regressive marine slope deposit, brackish lacustrine sediments, a deltaic sequence, and nonmarine flood plain sediments. These cores record the continuous depositional history, environments, and facies changes of strata ranging from early Miocene to Holocene and represent an unique record of sedimentation. Understanding of these depositional environments will greatly aid in the interpretation of other core data obtained from other wells throughout Hungary.

ACKNOWLEDGEMENTS

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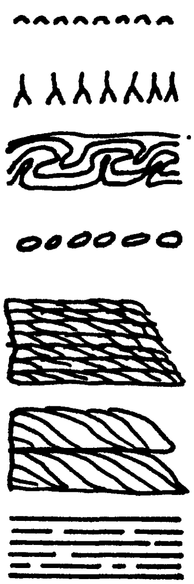
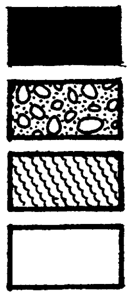
EXPLANATION



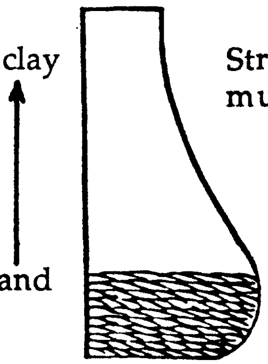
Shells
Root structures
Deformed strata
Rip-up clasts
Small-scale crossbeds
Large-scale crossbeds
Planar laminations



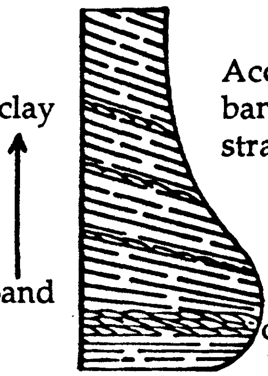
Lignite
Conglomerate
Schist
Structureless (sedimentary structures not preserved or not observed)

FLOOD PLAIN ENVIRONMENT

Fluvial distributaries

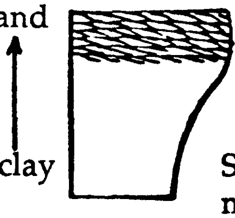


Fining-upward cycle

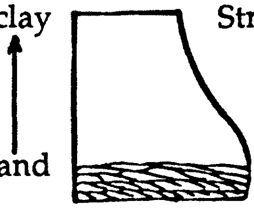


Fining upward cycle

Crevasse splay and overbank deposits



Coarsening-upward



Fining-upward