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Sedimentological Investigations in the Early Miocene Lignite Opencast Mine Oberdorf (N Voitsberg, Styria, Austria)

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10 Text-Figures

Styria
Pannonian Basin
Styrian Basin
Lignite
Early Miocene
Sedimentology

Österreichische Karte 1 : 50.000
Blatt 163

Contents

Sedimentologische Untersuchungen im untermiozänen Braunkohlentagebau Oberdorf (N Voitsberg, Steiermark, Österreich)

Zusammenfassung

Die siliziklastischen Sedimente der frühmiozänen, kohleführenden Köflach-Voitsberg-Formation sind überwiegend der Randfazies eines fluviatilen Environments zuzuordnen. Charakteristische Sedimente der Überflutungsebene und flacher Überflutungsdepressionen wechseln mit Dammdurchbruchsedimenten und Rinnensedimenten.

Die Entwicklung von Paläoböden ist häufig und wird charakterisiert durch Roterdehorizonte oder bläulich-grünliche, Siderit-führende Lagen, welche indikativ für wassergesättigte Böden innnerhalb eines Sumpfenvironments sind. Das häufige Auftreten von Fusainlagen deutet auf das regelmäßige Vorhandensein von Paläowaldbränden hin. Die Schwermineralverteilung ermöglicht die Unterscheidung zweier unterschiedlicher Erosionsgebiete. Die Sedimente des Hauptzwischenmittel sind durch ein Liefergebiet der niedrig metamorphen oberen Grünschieferfazies geprägt, wohingegen das Liefergebiet der Hangendeinheiten eindeutig einem mittelgradig metamorphen amphibolitfaziell geprägten Liefergebiet zuzuordnen ist. Eine Modellierung des Kohleflözes ermöglicht eine Korrelierung der Oberdorf-Ostmulde mit der Oberdorf-Westmulde und dem Tagebau Zangtal und demonstriert weiters die komplexe Subsidenzgeschichte innerhalb der Becken.

Abstract

The siliciclastic deposits in the Early Miocene lignite-bearing Köflach-Voitsberg Formation can be predominantly associated with sediments of a marginal fluvial environment. Characteristic floodplain and floodbasin sediments are alternating with crevasse splay deposits and channel fillings. Palaeosols occur frequently and are characterized either by red earths, or bluish-greenish, siderite-bearing horizons giving evidence for waterlogged soils of a swampy environment. The frequent occurrence of fusain layers indicates palaeoforest fires. The heavy mineral distribution allows two distinct erosional areas to be differentiated: a low grade metamorphic upper greenschist facies source area in the main seam parting and a medium grade metamorphic amphibolite facies source area in the hanging wall sediments. The modelling of the coal seam distribution shows the correlation of the Oberdorf eastern subbasin with the adjacent Oberdorf western subbasin and the Zangtal opencast mine and demonstrates the complexity of the subsidence history within these basins.

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1. Introduction

The Neogene basin filling (Köflach-Voitsberg Formation, sensu EBNER & STINGL, this volume) reaches a thickness of more than 300 m in the region of the Köflach-Voitsberg lignite deposits. The environmental analysis on siliciclastic sediments in the Oberdorf and Zangtal opencast mines is designed to provide the first concrete answers to the question whether a marine influence existed at any time. The lacustrine-fluvial character of the sediments in the Köflach-Voitsberg lignite deposits, as opposed to the definitive marine deposits of the East Styrian Basin, has often been postulated but never proven (KOLLMANN, 1965, EBNER & SACHSENHOFER, 1991).

The investigations in the Oberdorf opencast mine, concentrate on the eastern subbasin and dealt, among others, with the Tertiary sediments in the footwall and the hanging wall sediments, as well as the main parting which divides the seam along the eastern margin. Additional investigations in the directly adjoining Zangtal opencast mine are not the subject of this paper but some results will be mentioned in comparison to the Oberdorf sediments. The reconstructed environments based on sedimentological data correspond with those of the palaeobotanical and coalpetrographic results (HAAS et al., this volume; KOVAR-EDER, this volume; MELLER, this volume; KOLCON & SACHSENHOFER, this volume; DAXNER-HÖCK [1] et al., 1998). A more detailed introduction of the multidisciplinary studies within this project is given in the contribution of STEININGER (this volume).

2. Methodology

The environmental interpretation of the available data is based on a combination of the sedimentary cyclicities observed in both field outcrops and in drill cores, a granulometric evaluation using facies-sensitive methods, and an evaluation of the diagenesis from thin-section analyses. Due to the regionally high content of organic material in the clastic sediments of the lignitic layers, the investigation of TOC (total organic carbon) gives information about local environments producing high rates of organic material that is often preserved in dependence on the average siliciclastic grain size distribution (TYSON, 1995).

The investigated data were submitted to X-ray powder diffraction analyses and scanning electron microscopy. The determination of different source areas was made by investigating the distribution of heavy minerals.

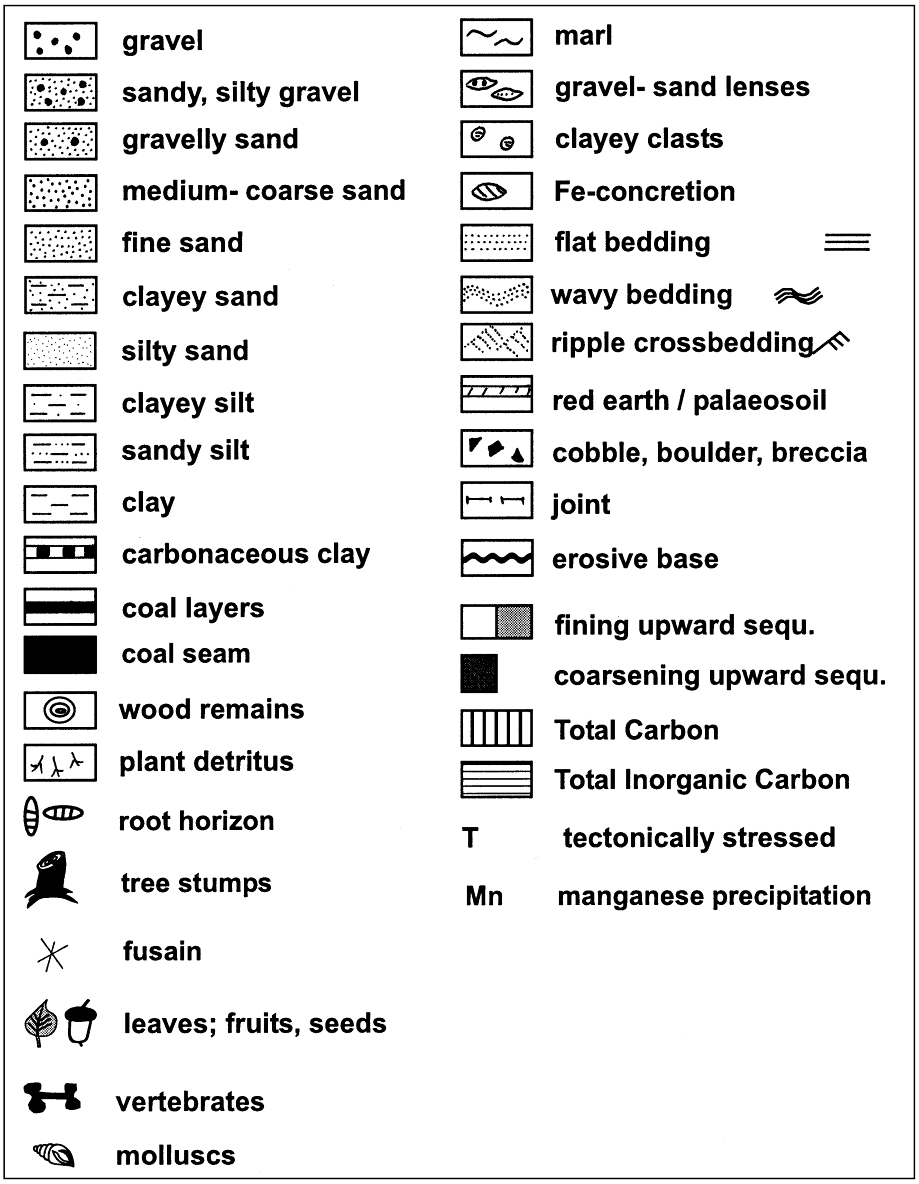
A contour model of the uppermost coal surface and the lowermost coal surface should give an answer to whether the seam of the Oberdorf eastern and western subbasin can be correlated and if there is a relation to the Zangtal upper and lower seam. This model is generated using triangulation as method of calculation.

3. Sedimentology

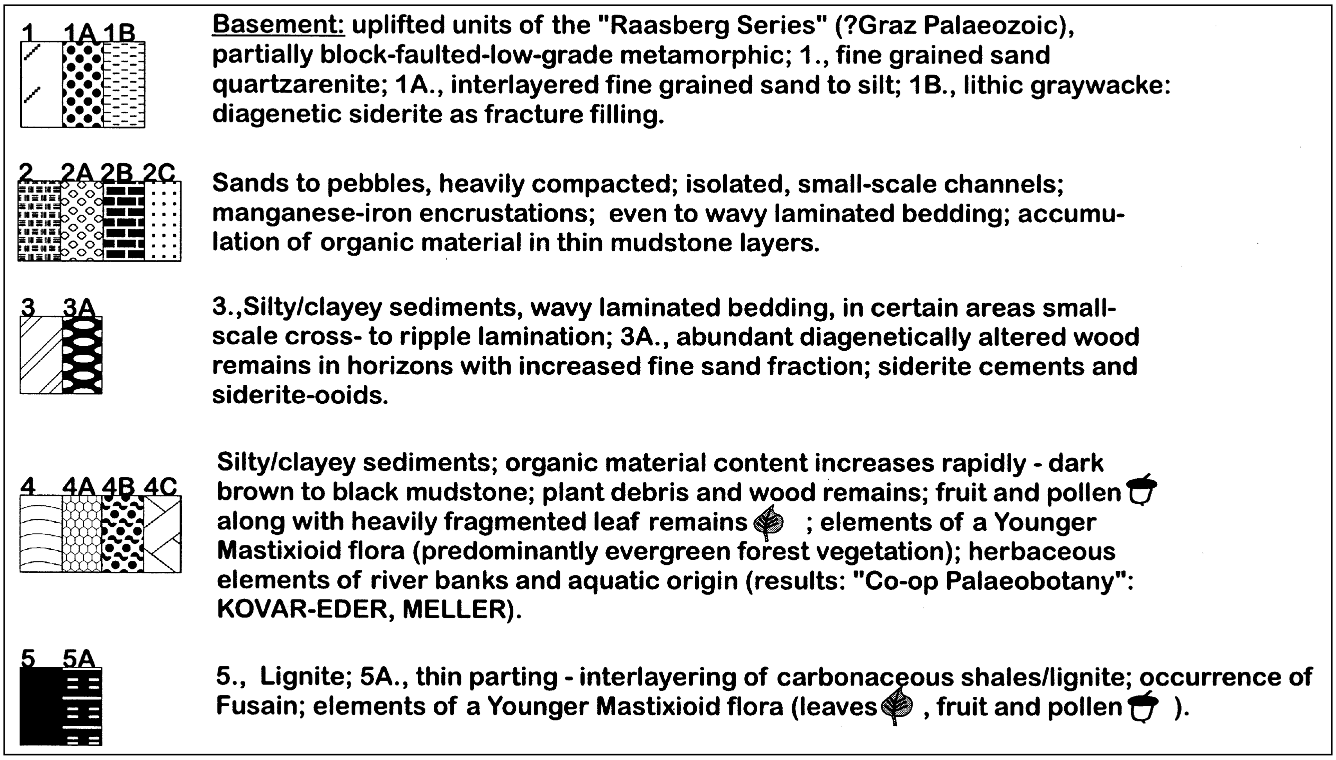
3.1. Sedimentology of the Footwall Sediments

The footwall sediments in the eastern subbasin of the Oberdorf opencast mine can be assigned to a marginal facies of a fluvial environment (Text-Figs. 2 and 3, legend: Text-Fig. 1), although a short term lacustrine influence cannot be excluded.

The sedimentation cycle was initiated by sandy-gravelly sediments typically with even to wavy bedding and abundant manganese and iron encrustations. In the uppermost section, the direct fluvial influence decreased and overbank sediments were deposited. The characteristic log-probability curve of grain size distribution (VISHER, 1969) clearly points to a marginal facies depositional milieu of a low-gradient



Text-Fig. 1.
Legend for Text-Figs. 3, 5 and 7.



Text-Fig. 2.
Differentiation of lithofacies in the footwall (legend to Text-Fig. 3).

fluvial environment. The low-energy current area is characterized by the sedimentation of floodplain and crevasse deposits. The general fining upward within the sequence is initiated by a short-term coarsening upward deposit, reflecting the start of a fluvial influence. The increase in organic material is obvious in the TOC content (TC-TIC) as well as in the cyclic appearence of horizons with diagenetically altered, oxidized organic material which indicates that former root horizons are present. The siliciclastic sedimentation is increasingly replaced by organic sedimentation and merges into the lower seam. The frequent occurrence of fusain layers indicates forest fires. Such phenomena are known from recent subtropical to tropical swamps and play a system-regulating role (Stach et al., 1982).

The palaeobotanical results from the investigation of two horizons in the upper part of the profile are comparable with the sedimentological results. Species-rich plant communities of various sites from mesophytic forests to river bank vegetation and aquatic elements have been recorded (Kovar-Eder et al., Meller et al., in press).

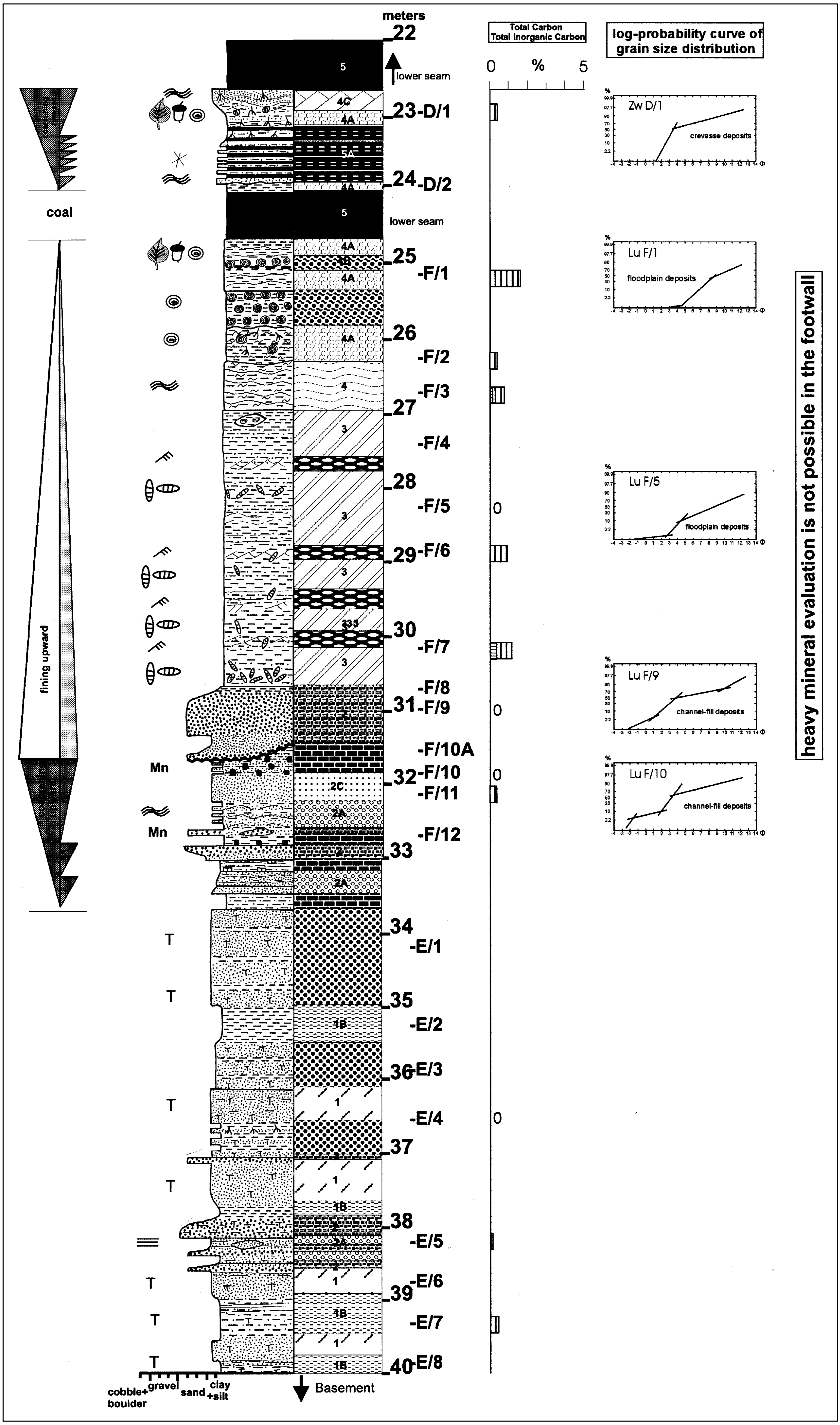
The total carbon (TC) content in the sediment ranges from 0 to 1.5 %, whereby the fine-grained sediments contain most of the organic material. The occasional elevated "inorganic carbon" content can be largely attributed to the occurrence of siderite. XRD and thin-section analyses revealed no noteworthy amounts of other carbonates. Siderite occurs in the Tertiary sediments of the footwall as radially organized, spherical structures with a series of concentric shells. A prerequisite for the formation of siderite which as an early diagenetic structure occurs with a concurrent absence of iron sulfide minerals such as pyrite, is a high concentration of carbonate ions and an only weakly effective sulfide ion concentration. Such conditions are rare in the sediment pore waters of marine-influenced environments, due to the high sulfate content. Further analyses by scanning electron microscope are necessary to ascertain whether the siderite derived from fresh water or marine influenced environments (Mozley, 1989), although recent investigations indicate the influence of bacteria on the elemental composition of early diagenetic siderite (Mortimer et al., 1997). Furthermore, the occurrence of siderite ooids could be explained by waterlogged soils in a swamp. These will be described below from the hanging wall sediments. These factors have to be taken into account when using siderite as a palaeoenvironmental indicator.

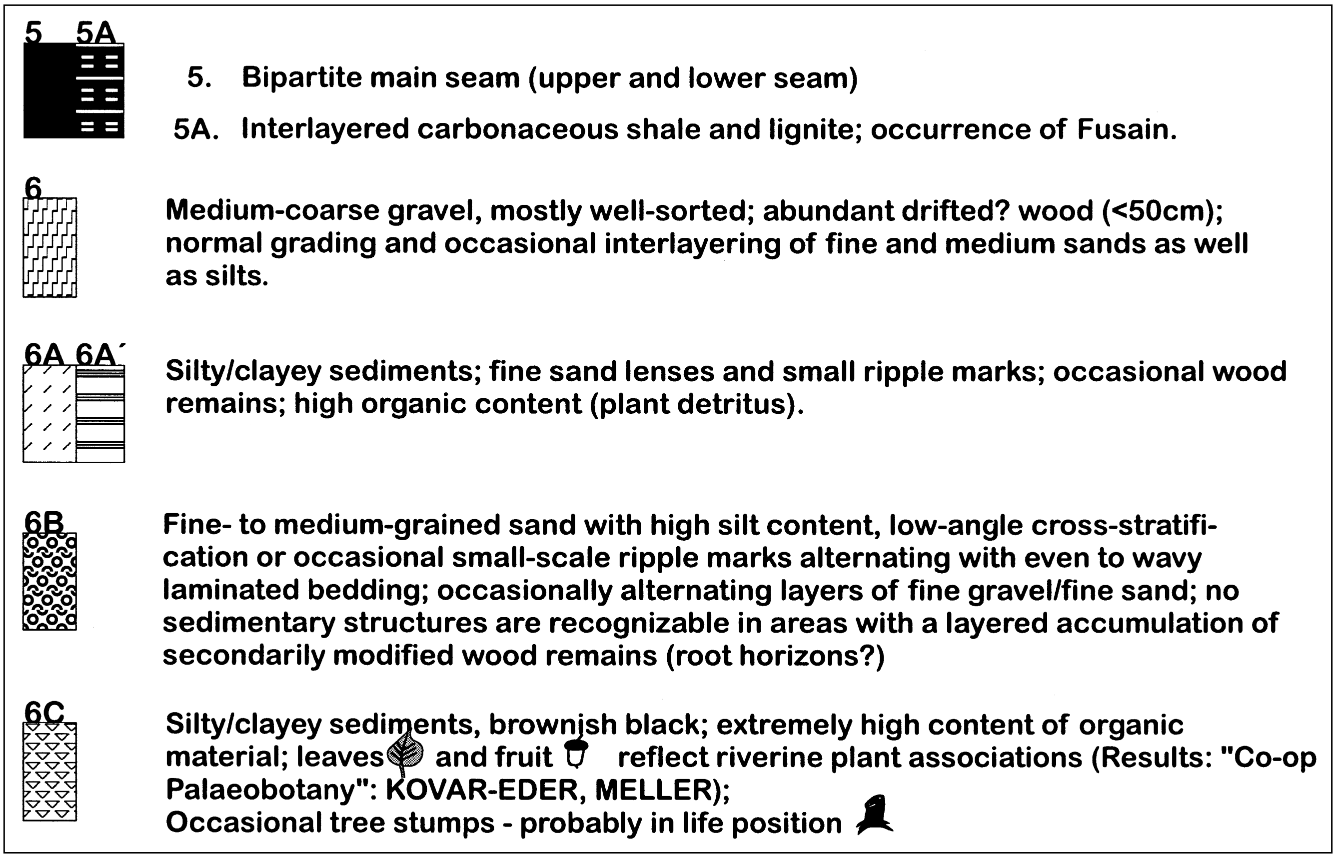
The mineralogy of a sediment with a lapilli-like structure in an approximately 3 to 7 cm thick layer in the uppermost part of the footwall sediments was investigated by thin-section analyses and XRD-analyses. The material was of high interest for a dating of the basal sedimentary units in the Oberdorf opencast mine. The data showed an already completely altered material with a 97 % kaolinite content. Further investigations, such as SEM and XRF-analyses are in progress, but a precise stratigraphic dating will probably be impossible.

The pre-Tertiary basement, which is exposed at the eastern margin of the eastern subbasin, consists of low-grade metamorphic Upper East Alpine units of the Graz Palaeozoic. Due to the uplift of Palaeozoic rocks, the basal Tertiary sediments form a dome-like structure with about 1 m of sediments preserved on top. About 15 metres of these sediments are exposed away from the basement. The compression of the sediments resulted in frequent small-scale folding ("slumping-like" structures). The period of tectonic influence is therefore considered to be syn- to post-sedimentary.

3.2.. Sedimentology of the Main Parting

Along the eastern subbasin, an approximately 22 m thick main parting (Text-Figs. 4 and 5, legend: Text-Fig. 1)


meters
Total Carbon
Total Inorganic Carbon
0 % 5
log-probability curve of grain size distribution
coarsening upward
coal
fining upward
coarsening upward
lower seam
lower seam
22
23-D/1
24-D/2
25
-F/1
26
-F/2
-F/3
27
-F/4
28
-F/5
29-F/6
30
-F/7
-F/8
31-F/9
-F/10A
32-F/10
-F/11
-F/12
33
34
-E/1
35
-E/2
36-E/3
-E/4
37
38
-E/5
-E/6
39
-E/7
40-E/8
Mn
Mn
T
cobble+ boulder
gravel
sand
clay +silt
Basement
Zw D/1
crevasse deposits
Lu F/1
floodplain deposits
Lu F/5
floodplain deposits
Lu F/9
channel-fill deposits
Lu F/10
channel-fill deposits
heavy mineral evaluation is not possible in the footwall



Text-Fig. 4.
Differentiation of lithofacies in the main parting (legend to Text-Fig. 5).

divides the main seam into an upper and a lower seam, which thins out considerably toward the center of the basin.

The sedimentological conditions in the main parting reflect a distinct sandy/silty development and differ considerably from the silty/clayey development of the footwall sediments. The rapid transition from sandy/fine-gravelly to silty/clayey sediments as well as the occurrence of small-scale ripple marks, decimeter-sized fine-grained sand lenses, and normal graded sediment layers point to a depositional milieu of a fluvial marginal facies with subordinate characteristics of a river-delta-environment. The sediments can be compared with recent distributary channel deposits, natural levee and crevasse deposits.

The increased organic sedimentation in the uppermost fining upward sequence is documented by elevated TOC contents (TC-TIC) (up to 3 %) in the siliciclastic sediments. This is due to both plant detritus, including often excellently preserved drifted wood remains, and also to secondary, diagenetically altered root horizons. The definitive proof of river bank plant communities in two horizons in the upper part of the outcrop (KOVAR-EDER, this volume; MELLER, this volume), as well as the isolated occurrence of tree stumps successively lead to a transition from the siliciclastic-dominated sedimentation to the organic-dominated sedimentation and the formation of the upper seam. Siderite and fusain are again present.

Text-Fig. 3. ◄◁◄
Sedimentological profile of the footwall sediments, including characteristic log-probability curves of grain size distribution as well as TC and TIC contents.

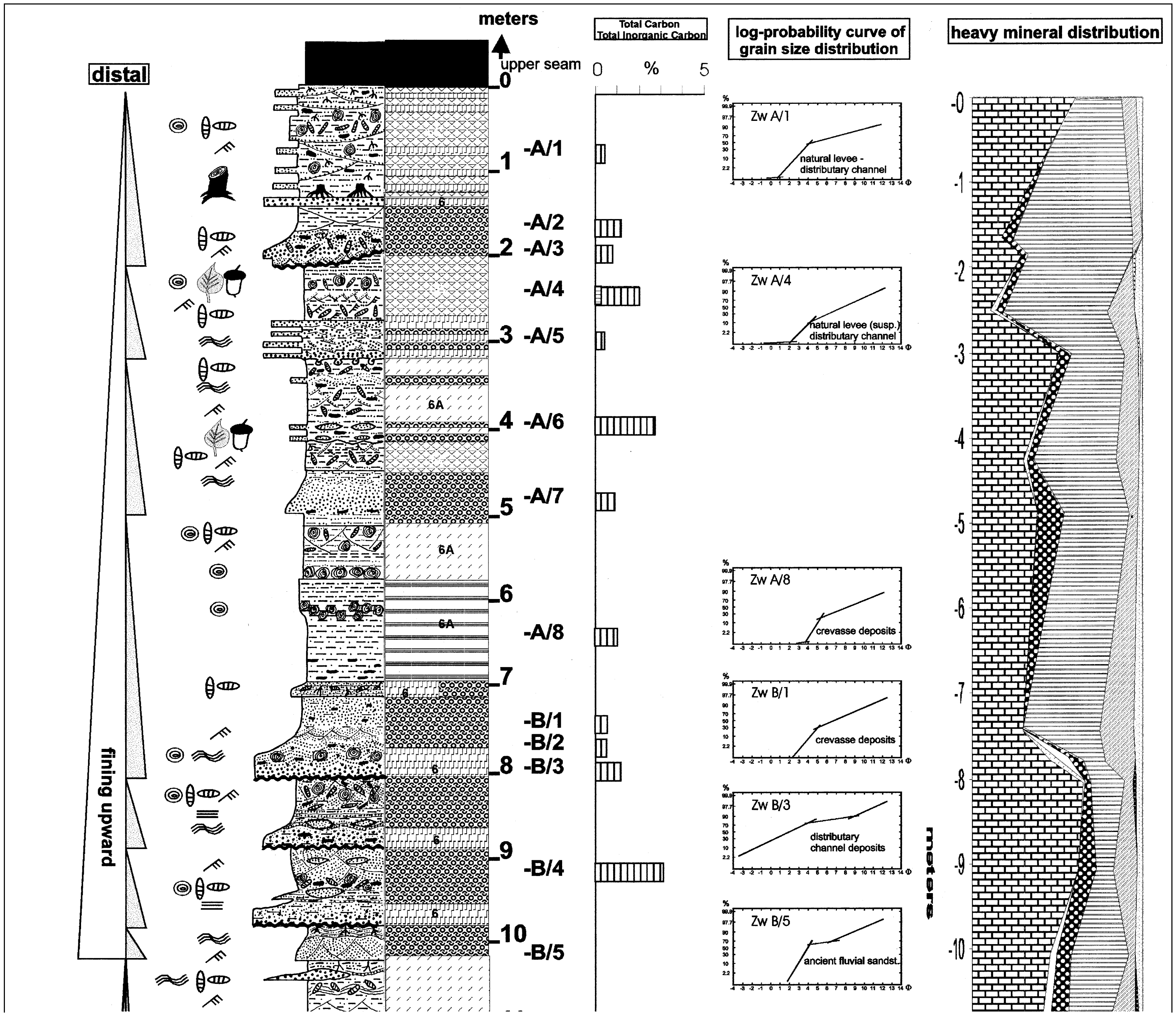
3.3. Sedimentology of the Hanging Wall Sediments

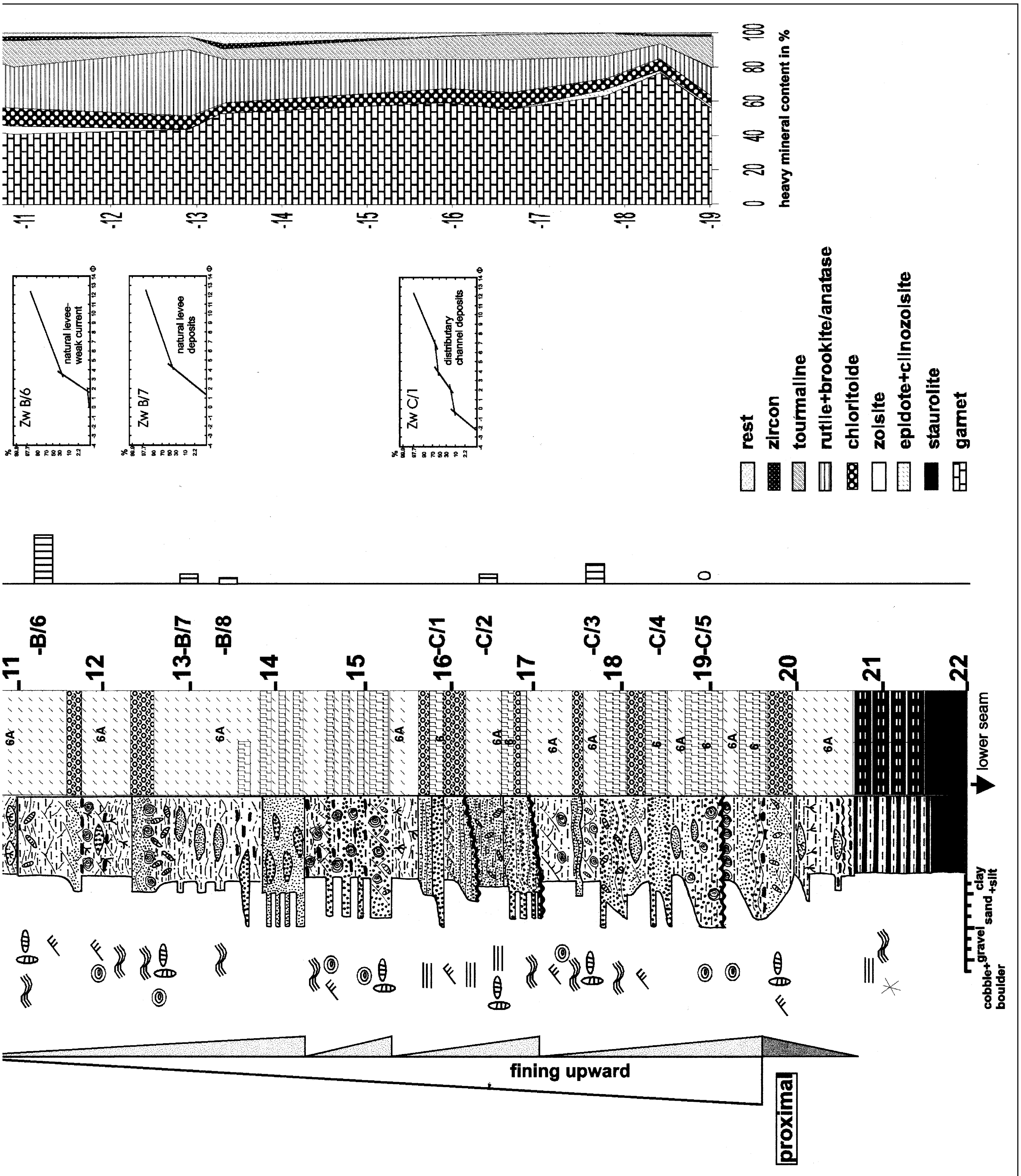
The sedimentological investigations of the hanging wall sediments are based on analysis of well I2a. The sediments of the hanging wall (Text-Figs. 6 and 7, legend: Text-Fig. 1) differ from the footwall- and main parting sediments in their granulometric occurrence, mineralogical composition and finally in their heavy mineral composition (see: next chapter).

The sediments of the basal hanging wall show extremely poorly sorted gravel and cobble/boulder sediments, with an angular shape of the components, interpreted as debris flow sediments. The following two fining upward sequences give evidence for sediments of a proximal fluvial sedimentary environment dominated by channel fill sediments and their marginal fluvial sub-environments such as current laminated sediments, natural levee and natural levee suspension deposits. The lowermost fining upward sequence shows coarse clastic sediments developing into silty, clayey sand and fine gravel. Well sorted sand and fine gravel lenses are frequent, as well as Fe-concretions and sulphurous residuals. Short-term intercalations of carbonaceous clay, with plant detritus and leaf remains give evidence of low energy environments such as floodplain and floodbasin sediments typical for back swamps.

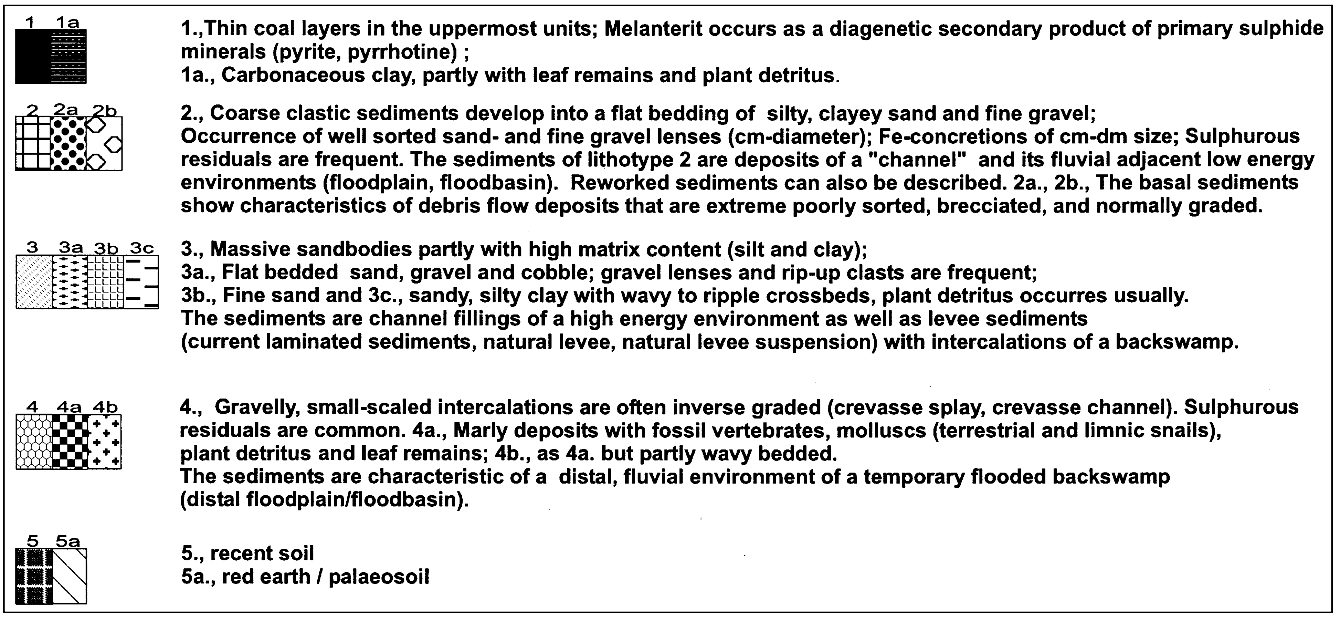
The red earth layer in the upper part of the profile developed under oxic influence and can be related to a palaeosoil, indicating a time gap with a low up to zero sedimentation rate. The overlying uppermost fining upward sequence is interrupted by some small coarsening upward sequences representing crevasse splays and crevasse

Text-Fig. 5.
Sedimentological profile of the main parting, including characteristic log-probability curves of grain size distribution as well as TC and TIC contents and the heavy mineral distribution.





rest
zircon
tourmaline
rutile+brookite/anatase
chloritoide
zoisite
epidote+clinozoisite
staurolite
garnet
heavy mineral content in %
Zw B/6
natural levee-weak current
Zw B/7
natural levee deposits
Zw C/1
distributary channel deposits
lower seam
cobble+boulder
gravel
sand
clay+silt
fining upward
proximal



Text-Fig. 6.
Differentiation of lithofacies in the hanging wall sediments (legend to Text-Fig. 7).

channel deposits. The sequence also shows characteristic floodplain sediments and levee deposits, with wavy bedding, and can be defined as a distal, fluvial environment of a temporary flooded back swamp. The occurrence of bluish/greenish palaeosols is characteristic for waterlogged soils (RETALLACK, 1997). This type of soil (surface water gley) develops in flat floodbasins of back swamp areas due to the reduction of Fe^{3+} to Fe^{2+}. The following precipitation of Fe^{2+} and the forming of sphaerosiderite, siderite ooids, as well as iron concretions are indicative secondary products of the above mentioned mobilisation of iron in the hanging wall sediments. The latter gives additional hints for a subtropical to tropical palaeoclimate (DAXNER-HÖCK [2] et al., 1998).

Sulphurous residuals are frequent, as well as partly high contents of primary carbonate components (up to 5 % calcite, 16 % dolomite), giving the sediments a marly character. The massive occurrence of primary carbonate can only be found in these upper units and is completely absent in the footwall sediments and the main seam parting. The investigated coaly layers (KOLCON, SACHSENHOFER, this volume) are indicative of neutral or even slightly basic pH-conditions, due to their sulphur content. The sediments below the biparted coaly layer (the uppermost is divided by a small parting) are therefore rich in fossil molluscs (terrestrial and limnic snails) and vertebrates. Plant detritus, leaf remains, fruits and seeds are found. This is the only horizon, which can be correlated by palaeozoological and palaeomagnetic data (STEININGER et al., this volume).

In the upper biparted coal layer the secondary mineral product melanterite occurs. This was derived from primary sulphides like pyrite and is an iron sulphate with the formula $FeSO_4 \times 7(H_2O)$. At its dissolution it can release sulphuric acid and this may have been responsible for the dissolution of primary carbonate components and fossils in the Oberdorf opencast mine.

The total carbon content ranges up to 52,96 % in carbonaceous clays but mostly it lies between 0 and 5 %. The total inorganic content in the uppermost fining upward sequence derived nearly exclusively from primary calcite and dolomite, whereas in the sequences below the red earth layer siderite is the most common inorganic carbonate.

4. Heavy Mineral Distribution

The current status of sedimentological research in the region of the Oberdorf opencast mine allows two distinct erosional areas to be differentiated (Text-Fig. 5 and Text-Fig. 7). The heavy mineral content of the footwall sediments was extremely poor and for a statistical analysis not suitable.

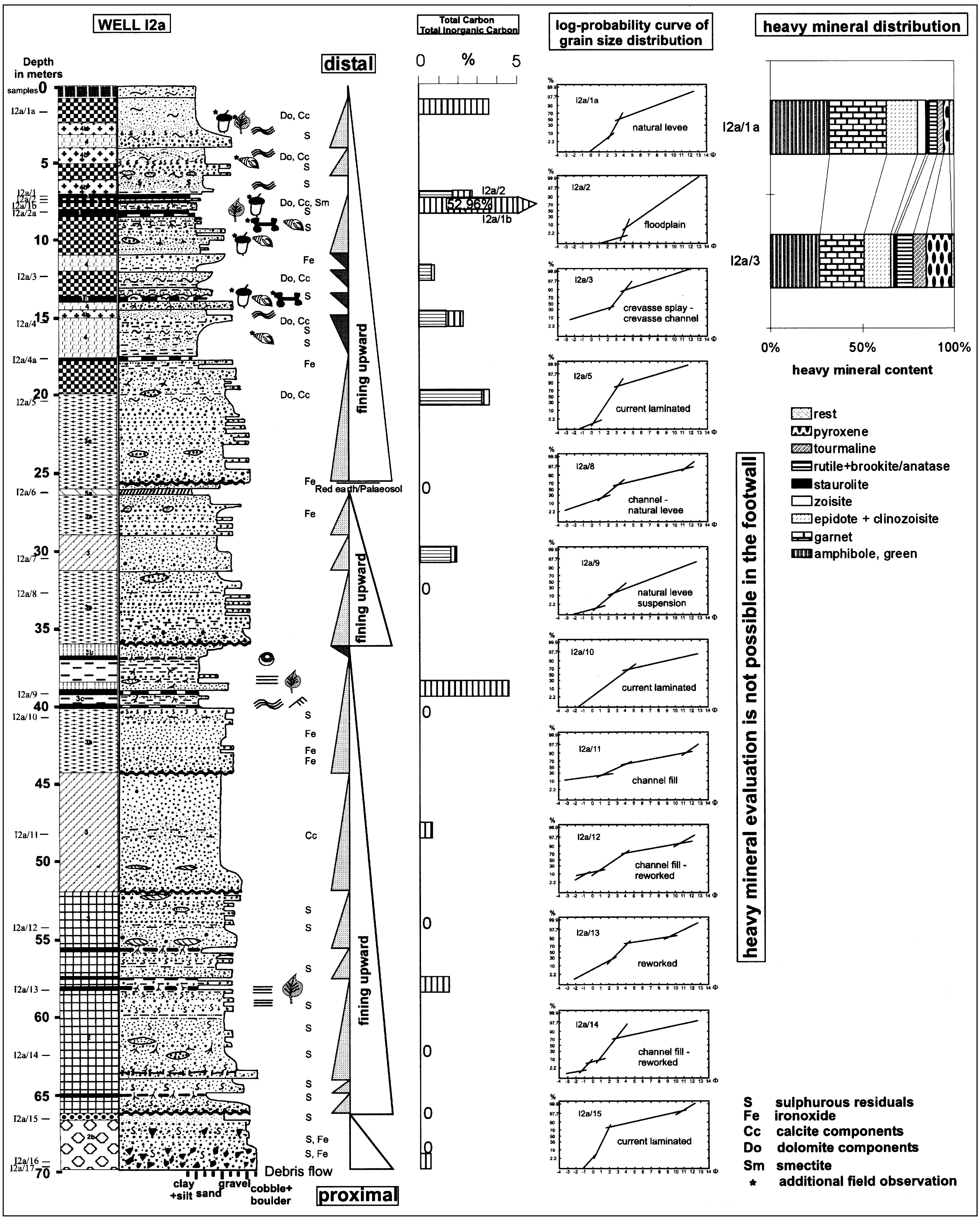
In the main parting a significant garnet-chloritoid-dominated heavy mineral spectrum is evident within the siliciclastic lignite-bearing layers. The source area is defined as having undergone an upper greenschist facies, low-grade metamorphism, showing a characteristic absence of staurolite, green hornblende and zoisite. The introduction of reworked Gosau sediments can not be excluded.

The siliciclastics of the hanging wall sediments show obvious differences in their heavy mineral distribution, although only two samples of the uppermost units have been investigated, whereas the others were already altered or heavily iron-encrustated. These have a garnet-green hornblende-staurolite-zoisite (+ epidote and clinozoisite) assemblage, suggesting a source area which underwent a medium grade metamorphism amphibolite facies.

Comparison of the heavy mineral distributions in the main parting of the adjacent Zangtal opencast mine with the hanging wall sediments of the Oberdorf opencast mine shows clearly that they have a similar composition. That leads to some reflections about seam correlations in the next chapter.

5. Coal Seam Modelling

The development of a main seam in the western and eastern subbasin of the Oberdorf opencast mine lead to the question whether these two subbasins are correlatable and whether the seams can be directly correlated.



Text-Fig. 7.
Sedimentological profile of the hanging wall sediments, including characteristic log-probability curves of grain size distribution as well as TC and TIC contents and the heavy mineral distribution.

Text-Figs. 8 and 9 show a contour model of the uppermost coal surface and the lowermost coal surface, being generated from 270 drill cores. Text-Fig. 10 shows the total stratigraphic thickness between the uppermost and lowermost surface including the main partings in both subbasins. The sedimentologically investigated outcrops and wells are plotted within the map as well as the position of well 304 being investigated by KOLCON & SACHSENHOFER (this volume). Text-Figs. 8 and 9 give evidence that the eastern and western subbasins were connected and the seams developed in the same time period. The model of the lowermost coal surface shows a strong relief that is generated by increasing subsidence, being necessary for the accumulation of coal bearing strata whereas the contour model of the uppermost coal surface shows a smoother relief, giving evidence for reduced subsidence activities that finally leads to the end of organic sedimentation.

The transition of the main seam of the Oberdorf eastern subbasin to the adjacent opencast mine Zangtal could also be defined and gives evidence that the uplift of the basement separating the two basins took place in a postsedimentary event. The Zangtal upper seam is a younger development and is not pictured in these Figures. The heavy mineral distribution of the Zangtal main parting correlates with the heavy mineral distribution of the hanging wall sediments in the opencast mine Oberdorf. Whether or not the biparted small coal layers in the hanging wall can be correlated to the Zangtal upper seam is being investigated in the still ongoing investigations.

6. Conclusion

The sediments of the Oberdorf opencast mine are deposits from proximal and distal fluvial depositional environments. The sediments are channel deposits, as well as its marginal fluvial deposits like levee, floodplain and floodbasin sediments giving evidence for a back swamp environment. Subordinate characteristics of a river-delta-environment can be defined. The often postulated marine influence of the Paratethys can be excluded.

In the Oberdorf opencast mine the heavy mineral distribution changes vertically from the main parting to the hanging wall, defining a change of the source area. The composition in the hanging wall is comparable with the heavy mineral distribution of the main parting in the adjacent Zangtal opencast mine. However the subsidence history is complex and is still being investigated.

Reconstruction of the seam development of both basins, including internal subbasins, suggests a transition from the Oberdorf main seam to the Zangtal depositional area. It can be respectively correlated to the Zangtal lower seam.

Acknowledgements

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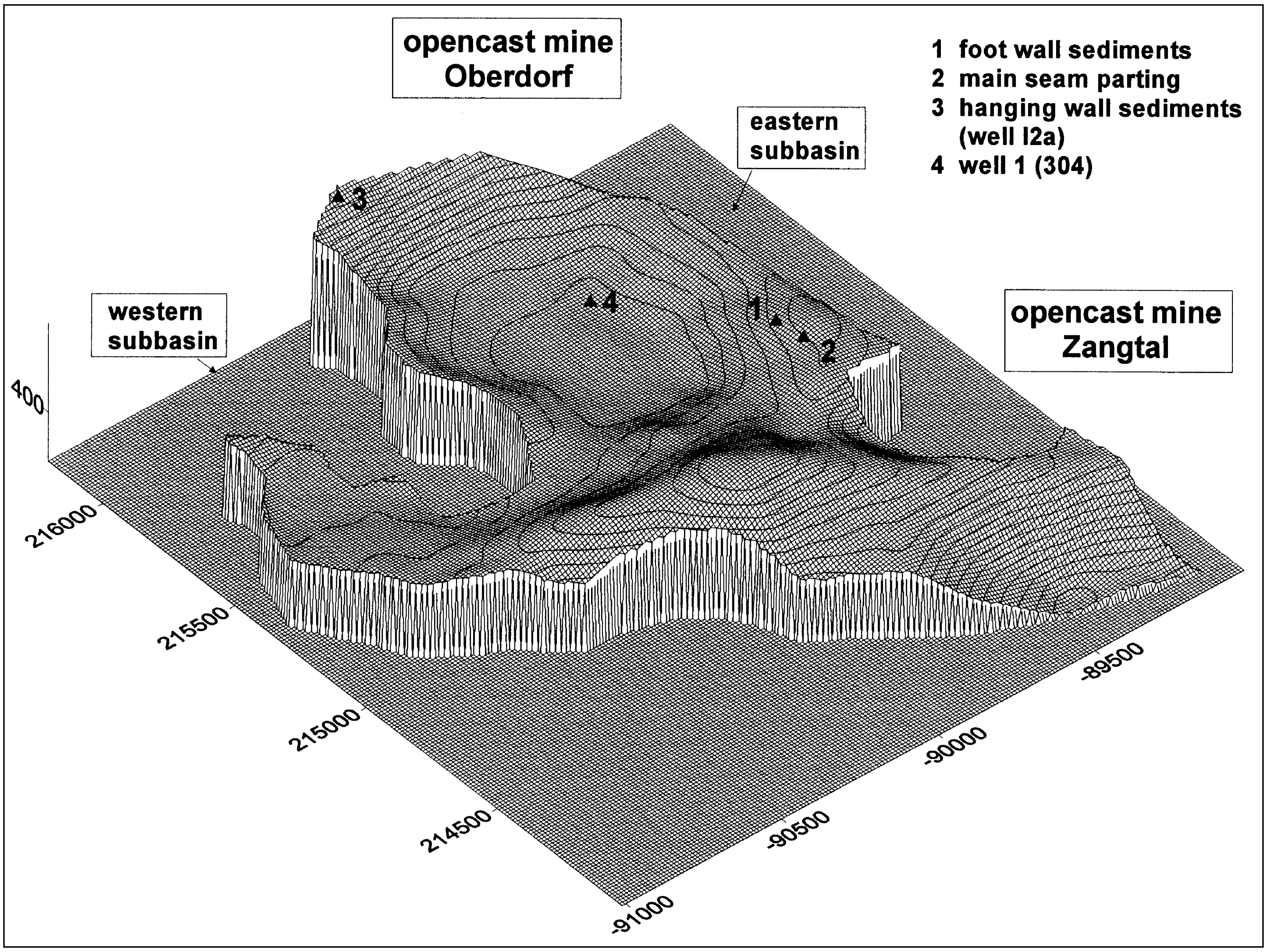
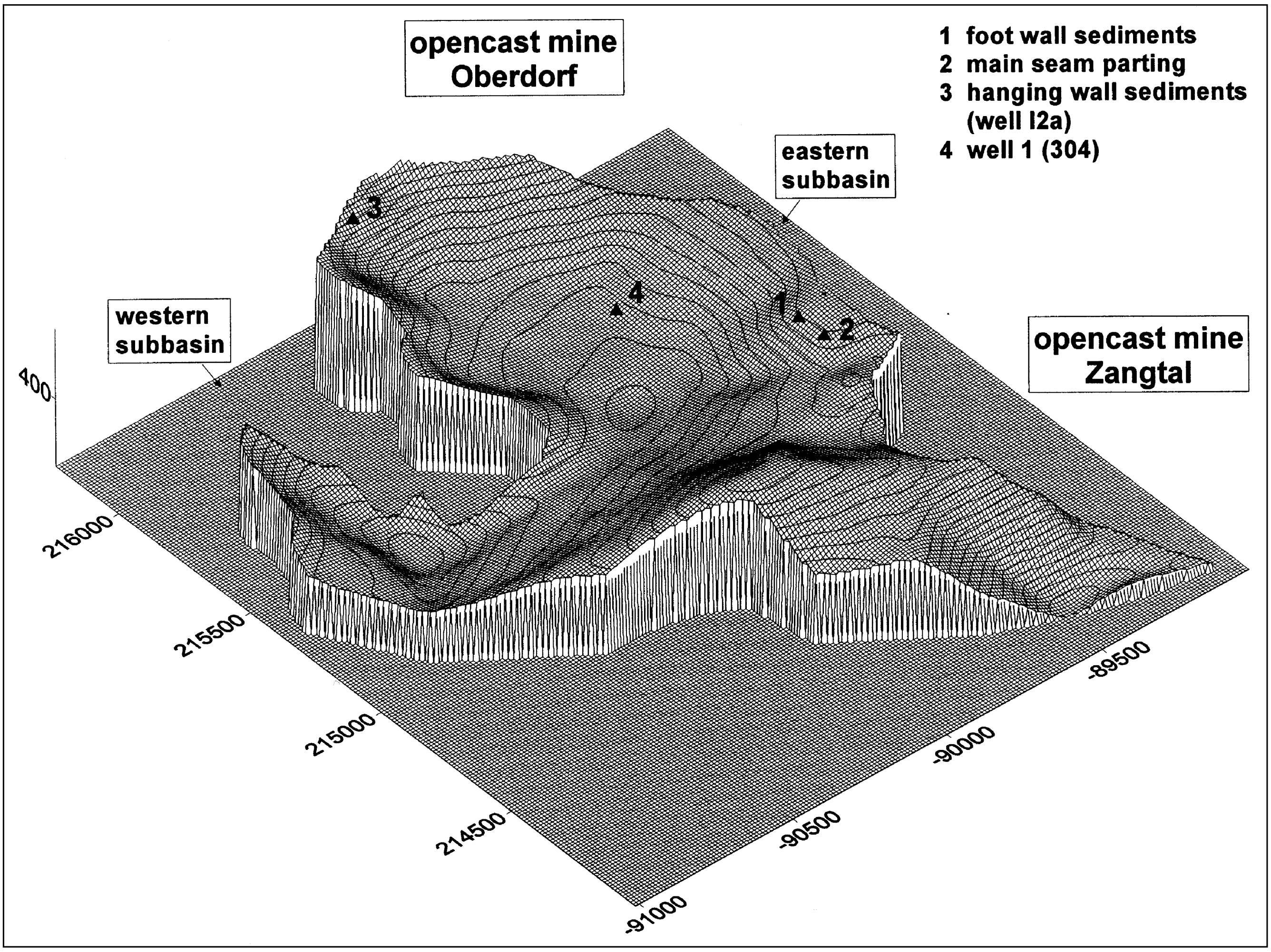
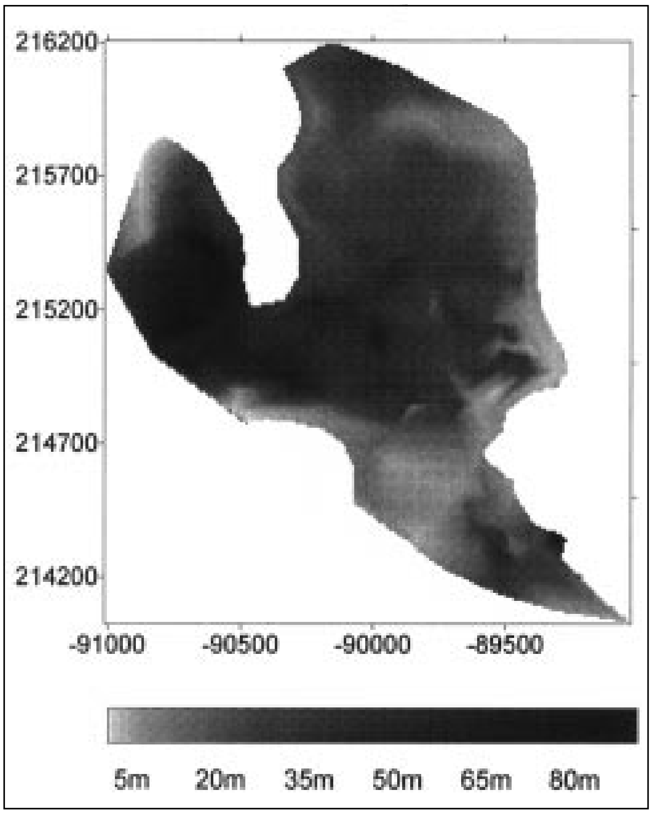


Text-Fig. 8.
Contour model of the uppermost coal surface (model two times superelevated).



Text-Fig. 9.
Contour model of the lowermost coal surface (model two times superelevated).



Text-Fig. 10.
Contour plot showing total stratigraphic thickness between uppermost and lowermost surface.

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