

SUMMARY OF GEOLOGY AND HYDROGEOLOGY OF THERMAE BOREHOLES (SOUTH-LIMBURG, THE NETHERLANDS)

by

Martin J.M. BLESS¹

(2 figures)

Between 28-11-1985 and 7-11-1986 three boreholes for thermal water have been drilled in Valkenburg a/d Geul (South-Limburg, the Netherlands). These have been named Thermae 2000, Thermae 2001 and Thermae 2002 after the THERMAE 2000 project, an ultra-modern thermal spa that will be established at the Cauberg in Valkenburg a/d Geul.

Thermae 2000 and Thermae 2002 yielded representative sections of the Cenozoic and Upper Cretaceous deposits in the Valkenburg area and penetrated the upper portion of the Dinantian rocks. Thermae 2001 was stopped in the Upper Cretaceous (fig. 1).

STRATIGRAPHY

Cenozoic sediments consist of Pleistocene loess (only recognized in Thermae 2002) and Oligocene sand of the Tongeren Formation. These have been determined only lithostratigraphically. At the base of the sand in Thermae 2000 and Thermae 2001 a basal conglomerate including rock fragments of Paleocene Houthem Chalk occurs. The Houthem Chalk has been identified by the presence of foraminifer assemblages characterizing Hofker's (1966) zone P.

Upper Cretaceous sediments consist of chalk (with abundant bioclasts in the upper portion; with flint and hard limestone intercalations in the lower two thirds) of the Maastricht and Gulpen formations and clayey sediments of the Vaals and Aachen formations. These have been dated by means of benthic foraminifera and palynomorphs. The chalk yielded foraminifer assemblages of the Upper Maastrichtian (foram zones C to M). The underlying slightly sandy, glauconiferous clay yielded foraminifer assemblages of the Lower Campanian (foram zone A'-lower). The poorly sorted mud-sand with kaolinic clay at the base of the Upper Cretaceous is characterized by palynomorphs suggesting an Upper Santonian age.

Quantitative analysis of bioclasts and ostracodes has permitted a detailed correlation of the marine Cretaceous in the Thermae boreholes. Comparison with other sections (notably ENCI and Halembaye quarries, Kastanjelaan borehole, outcrops near Heerlen such as RW76) has revealed that variations in the quantitative composition of bioclast and ostracode assemblages can be followed throughout South-Limburg. In this way it has been possible to recognize the posi-

tion of a.o. the Lichtenberg Horizon of the ENCI which forms the boundary between the Maastricht Formation and the underlying Gulpen Formation. These correlations are matched by the foraminifer zonation and by the GR logs of Thermae 2000 and Kastanjelaan-2. Serpulid assemblages occurring in the Upper Cretaceous of Thermae 2000 corroborate these correlations and also yield information of the paleoenvironment.

The Dinantian rocks are capped by a kaolinic paleosol, the result of intense lateritic weathering during presumably Jurassic and Lower Cretaceous. Lithologically this paleosol is very similar to the overlying mud-sand at the base of the Upper Cretaceous. The latter is interpreted as local reworking from this paleosol. Silicified foraminifera from the paleosol do not permit to distinguish between uppermost Visean and Lower Namurian. However, the abundant presence of relatively large sclerotoid grains (0.2-0.5 mm) in the underlying black shales and silicified limestones suggests that this interval is of the same age as the upper V3b limestones and shales of the nearby Houthem borehole. The foraminifer assemblages in the silicified limestones and bioclastic grainstones characterize the Warnantian or Upper Visean (V3b γ). Some pronounced GR peaks in the Dinantian sequence of Thermae 2002 reflect the presence of K-bentonites, presumably volcanic ash layers, as shown by the analysis of shale samples. Similar K-bentonites are characteristic for the Upper Visean in Belgium.

COAL-PETROGRAPHY

The Dinantian black shales and (partly to completely silicified) bituminous limestones contain remarkably high amounts of organic matter. Up to 4 % C_{org} was noticed in the black shales and over 1 % C_{org} in the limestones. Comparably high C_{org} contents have been observed in the Middle Visean shales and limestones from the Heugem and Kastanjelaan boreholes in Maastricht. The coalification rank is very high (more than 5 % R_{max} for vitrinite and more than 4 % R_r for metabituminite). This matches the high

¹ Natuurhistorisch Museum Maastricht, Bosquetplein 6-7
6211 KJ Maastricht, the Netherlands.

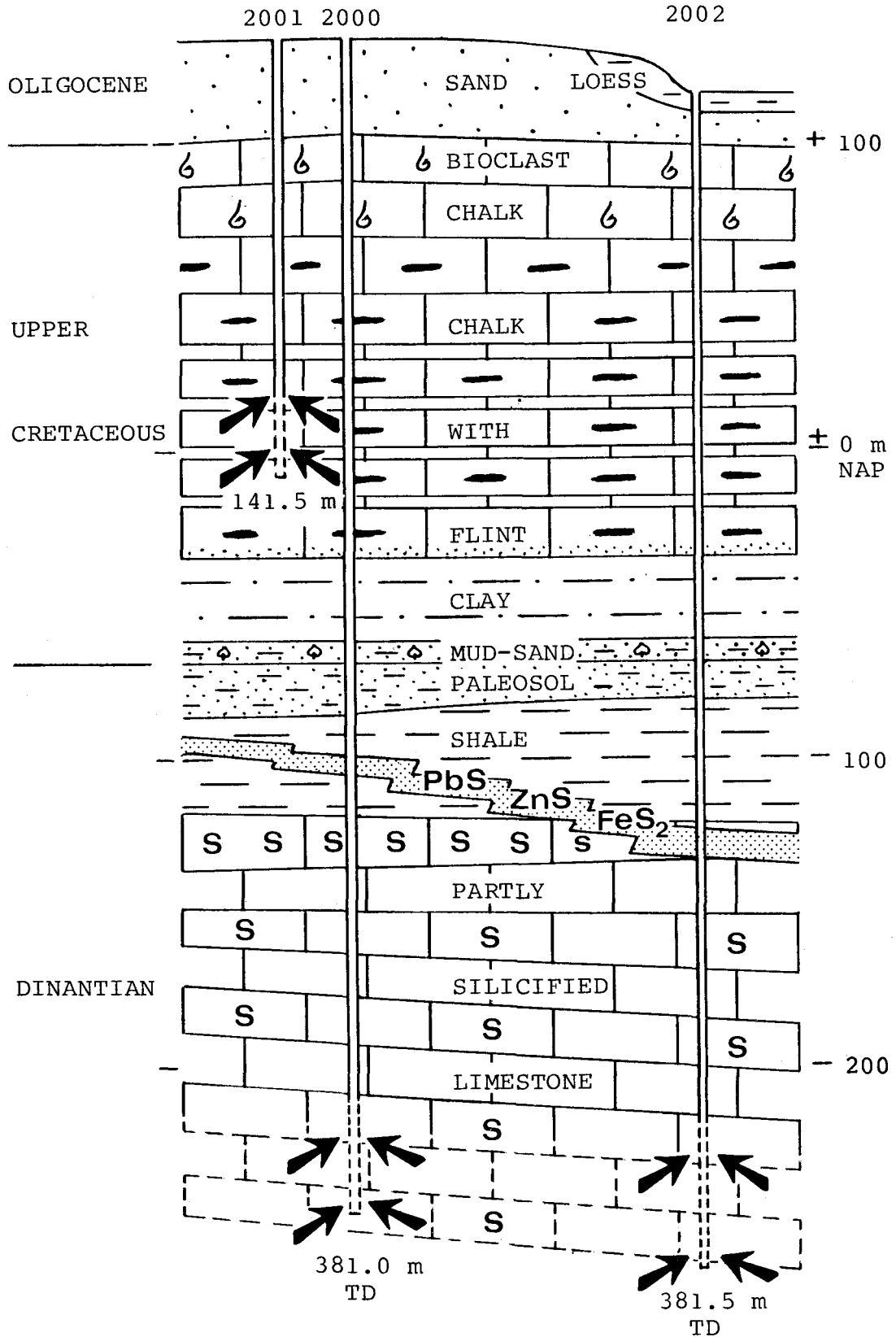


Figure 1 - Simplified section through Thermae boreholes, Valkenburg a/d Geul, South-Limburg, the Netherlands. Arrows indicate intervals with highest permeability in unconfined Cretaceous aquifer and confined Dinantian aquifer. «S» = silicified limestone.

ranks observed earlier for Middle Visean to Famennian rocks in Heugem and Kastanjelaan (5-7 % R_{max}) and for Namurian rocks in Cartiels near Gulpen (4.1 % R_f). The presence of vitroplast textures and mesophases suggests that the bitumen was affected by sudden, extreme heating (at least 450°C) before decomposition into gas, oil and dead kerogen. The origin of this heat flow is as yet unknown but may be related to the uplift of the Visé-Puth and Waubach blocks.

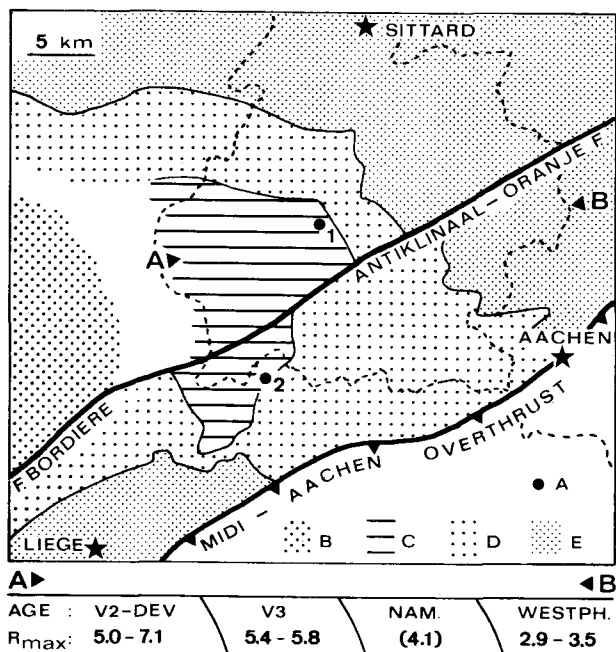


Figure 2 - Pre-Permian subcrop in South-Limburg and vicinity, showing presumed connection between Faille Bordière (southern border of Cambro-Silurian rocks of Brabant Massif) and Antiklinaal/Oranje Faults in former coal-mining area in South-Limburg.

Simplified cross-section A-B shows maximum reflectance of organic substance in Devonian to (Lower) Westphalian strata on both sides of inferred fault line. The anomalous high coalification rank of Devonian to (Lower) Westphalian strata proves that the heat flow has been post-Lower Westphalian. On the other hand the coalification rank must have been established before erosion of Upper Carboniferous strata took place in the Visé-Puth region. This suggests a Late Variscan age for the heat flow.

The high-rank coalification of the Carboniferous rocks in this area resembles that observed in the roof of the Bramsche Massif in NW Germany. There however the coalification is of Late Cretaceous age.

Legend : A = recent boreholes in Dinantian (1 : Thermae 2000-2002 ; 2 : 's-Gravenvoeren), B = Cambro-Silurian of Brabant Massif, C = Devono-Dinantian of Visé-Puth Uplift, D = Namurian, E = Westphalian.

SULFIDE MINERALIZATION

Important sulfide mineralization has been recognized in the Dinantian rocks of Thermae 2000 and Thermae 2002. It is a «schalenblende» ore with sphalerite, pyrite/marcasite and some galena. Colloform and idiomorphic pyrites from the sulfide ore are remarkably rich in arsenic (up to 4.82 weight-% As) but poor in copper and nickel.

Finely disseminated idiomorphic pyrites in the shales and limestones have a low content of arsenic (up to 0.09 weight-% As), but copper and nickel are relatively high (up to 0.49 weight-% Cu and up to 1.26 weight-% Ni). These latter seem to be related to the extremely high coalification rank. Coalification and Ni-Cu-rich pyrite may be pre-ore-formation, related to the uplift of the Visé-Puth and Waubach blocks.

The arsenic-rich pyrite occurring with sphalerite and galena in the «schalenblende» ore is restricted to karst cavities and fissures and was presumably derived from deeper-seated sources and transported by ascendent warm saline water.

HYDROGEOLOGY

Two aquifers have been recognized in the Thermae boreholes. The upper one is an unconfined aquifer in the Upper Cretaceous rocks. The main components of the water are calcium (75 epm%) and bicarbonate (72.5 epm%). This Cretaceous aquifer is separated from the lower one by an impervious layer of clayey deposits consisting of the glauconiferous, slightly sandy clay of the Vaals Formation, the kaolinic mud-sand of the Aachen Formation, the kaolinic paleosol on top of the Dinantian and the black shales in the upper portion of the Dinantian sequence.

The lower one is a confined aquifer in the Dinantian rocks. This water is a fluoride-containing Na-Cl thermal water according to the regulations of the Netherlands, the Federal Republic of Germany and the European Economic Community. The fluoride content is 2 mg/l (det. Institut Fresenius Taunusstein), Na^+ and Cl^- are both about 80 epm%. The temperature at the orifice of the well was 24.5°C on 18 april 1987. This water is bacteria-free and does not reveal any anthropogenic influence. Most likely, the low tritium content in the Dinantian aquifer is due to circulation losses during the drilling process.