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Bituminous Posidonienschiefer (Lias epsilon) of Mont Terri, Jura Mountains

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Introduction

In the course of an extended field investigation of bituminous rocks, a number of surface and well sections, covering the Lias epsilon (lower Toarcian) or at some places the whole Lias, were studied in Western Europe.

Natural outcrops of complete Lias sections being rare, the Posidonienschiefer of the Mont Terri in NW Switzerland proved an invaluable link between the excellent Lias outcrops of Aubächle in Württemberg and of Fontaneilles near Millau in S France.

During the summer of 1957, a survey of the Swiss table and folded Jura found the best profiles exposed to occur in the Mont Terri area and the following locality was chosen at the south flank of this anticline: the co-ordinates are 578,76/247,91 of the «Landeskarte der Schweiz, 1 : 50,000, Blatt 222, Clos du Doubs». The location lies 7 km SE of Porrentruy, about 1 km S of Mont Terri and 250 m due N of Pt. 857.

At this place, locally referred to as «Les Efougelles», the Posidonienschiefer is developed as bituminous shale 17 m thick and a complete section between the underlying ? Spinatus-Obliqua beds and the overlying Jurensis marl could be exposed along a small creek with little digging.

A. SCHNEIDER carried out the field survey and collected 43 samples from this locality. At the laboratory, in Delft, most of the rock specimens were studied sediment-petrographically by A. FEHR and eight selected samples were analysed geochemically by J. A. GRANSCH and P. A. SCHENK under the supervision of E. EISMA. Micropalaeontologic investigation was done by J. BROUWER, while the palynological studies were carried out by Miss M. BROSIUS.

In the following, a brief account of the results of these studies is given (see fig. 1), comparing some of them with the information obtained from other Lias sections in western Europe which were investigated by S. B. SPIJER, R. M. M. MOULLARD, H. F. JANSEN and P. BITTERLI during 1957—59.

Previous investigations

Apart from earlier work, the Posidonienschiefer of Mont Terri has attracted attention during the war-years as a potential source of hydrocarbons.

In this connection, a detailed field survey was carried out by P. KELTERBORN for the Swiss Mining Office, and the geological results were published in 1944. Later, E. RICKEN-

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BACH (1947) discussed in some detail both the stratigraphy of the bituminous shale section, and the results of a geochemical analysis made by the Federal Institute for Material Testing.

In the latter publication a Posidonienschiefer section 19.5 m thick is described from the locality «En Méchaimé» lying 480 m due W of our profile. As little change in facies takes place over this distance, detailed comparison between the two sections is thus possible and the more interesting as RICKENBACH also gives the results of an analysis of the bitumen content (dry distillation) of eight samples.

Stratigraphy

The lower boundary of the Posidonienschiefer has been placed at the contact between the non-bituminous marl (sample no. 34) and the first (basal) bituminous shale (sample no. 35), although no strong palaeontological evidence could be found to support this assumption for this locality. The upper contact lies at the top of a thin limestone band (sample no. 75) above the higests bituminous shale (sample no. 74), below the Jurensis marl (sample no. 76). Here again, this boundary may be somewhat arbitrary, but it appears fairly well established, being based on lithological grounds and on comparison with other areas.

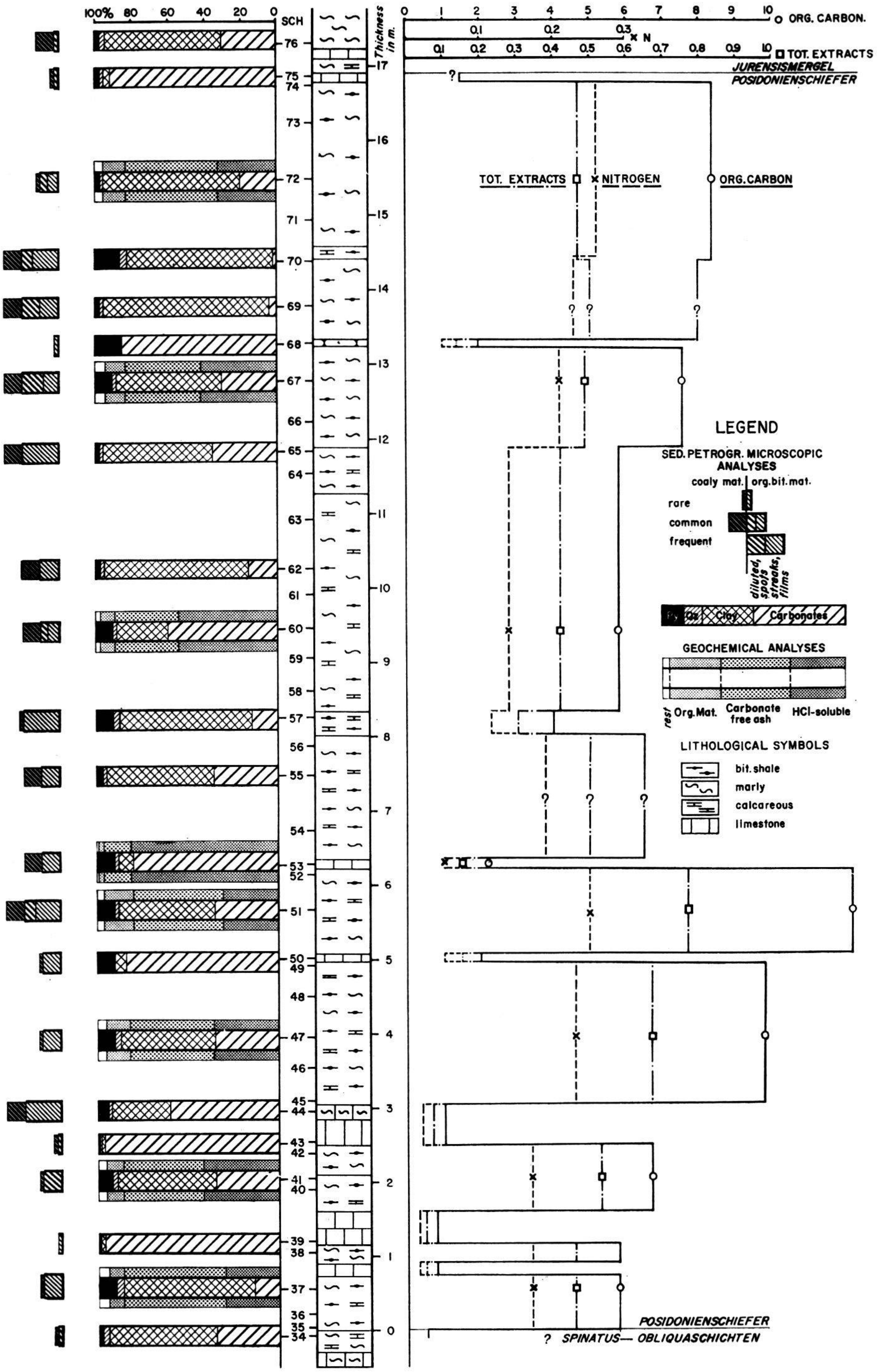
The lowest sample (no. 34), possibly belonging to the Lias delta, contained besides abundant *Lenticulina ssp.* and *Marginulina prima* d'ORBIGNY, frequent to common *Dentalina terqueni* d'ORBIGNY and *D. paucicurvata* FRANKE, *Lingulina tenera subprismatica* (FRANKE), *Marginulinopsis matutina* d'ORBIGNY, *M. breoni* (TERQUEM) and *Darbyella sp.*, and single specimens of a few other microforaminifera. A fimilar though somewhat poorer Lagenidae assemblage was found in samples no. 35—37, while higher up (samples no. 41, 45, 47, 59, 62, 63, 72) *Eoguttulina liassica* STRICKLAND prevails. In the (?) Jurensis marls (Lias zeta), sample no. 76 revealed a Lagenidae assemblage with abundant *Lenticulina subalata* REUSS, *L. münsteri* (ROEMER) and *Nodosaria dispar* FRANKE.

According to composition and distribution of these foraminiferal assemblages J. BROUWER assumes that the deposition of the Posidonienschiefer of Mont Terri took place in shallow quiet water, probably near shore, while the immediately underlying and overlying formations possibly are of a somewhat deeper origin.

The palynological examination of some of the samples revealed the presence of Leiosphaeridae, originally described by F. THIERGART (in B. BROCKAMP, 1944) as «*Sporites schandelahensis*» which we found to be widespread in western Europe: from Robin Hood's Bay in Yorkshire in the north over Bethel (Bielefeld), Göttingen, to Parbayón near Santander in the south. The occurrence of these globular bodies in the Lias of S Germany has been mentioned by EISENACK and others; they may represent ? crustacean eggs and according to Miss BROSIUS are indicative of a very specific, probably anaerobic environment. The composition and general aspect of the organic material of Mont Terri is, for instance, quite similar to that of Bethel (Bielefeld).

Sediment-petrography

The lithological composition of the Posidonienschiefer proper at Mont Terri shows, apart from a few thin limestone banks (Stinkkalk), a rather uniform development of medium to dark grey or dark brownish grey, well bedded, calcareous shales. Two grey



100% 80 60 40 20 0
SCH
Thickness in m.
ORG. CARBON.
x N
TOT. EXTRACTS
JURENSISMERGEL
POSIDONIENSCHIEFER
TOT. EXTRACTS
NITROGEN
ORG. CARBON
LEGEND
SED. PETROGR. MICROSCOPIC ANALYSES
coaly mat.
org.bit.mat.
rare
common
frequent
diluted, spots streaks, films
Py
Qz
Clay
Carbonates
GEOCHEMICAL ANALYSES
rest
Org.Mat.
Carbonate free ash
HCl-soluble
LITHOLOGICAL SYMBOLS
bit.shale
marly
calcareous
limestone
POSIDONIENSCHIEFER
? SPINATUS— OBLIQUASCHICHTEN

Figure 1

Table 1. Geochemical analysis of Mont Terri samples

Sample no.	% Moisture	% Extracts	% Nitrogen	% Org. carbon	% HCl-soluble	% Carbonate-free ash	Inorganic elements (Approximate %)						Trace elements (p.p.m.)				Ratios			
SCH							Ca*	Mg*	Fe*	Mn*	Al**	Si**	V	Ni	Mo	Cu	V:Ni	C:N	$\frac{E}{C \cdot 1000}$	$\frac{C \cdot E}{N \cdot \text{carbonate-free ash}}$
72	3.3	0.47	0.26	8.4	33	50	10	0.9	3.8	0.5	10	10	180	210	81	77	0.86	32	56	0.30
67	3.0	0.49	0.21	7.6	41	44	13	0.8	3.4	0.5	10	10	160	190	82	73	0.84	36	65	0.41
60	1.9	0.42	0.14	5.8	54	35	19	0.5	2.3	0.3	8	10	140	160	80	48	0.88	41	72	0.50
53	0.7	0.15	0.05	2.2	81	15	29	0.4	1.2	0.3	5	8	85	70	23	<20	1.2	44	68	0.44
51	3.3	0.77	0.25	12.2	31	49	10	0.7	3.6	0.3	10	10	230	290	100	78	0.79	49	63	0.77
47	3.2	0.67	0.23	9.8	36	46	11	0.8	4.2	0.3	10	10	220	230	41	90	0.96	43	68	0.62
41	2.6	0.53	0.17	6.7	42	44	16	0.8	3.9	0.3	10	10	130	160	<20	77	0.81	39	79	0.48
37	3.4	0.46	0.17	5.8	30	56	9	0.9	4.9	0.3	10	10	160	230	<20	93	0.70	34	79	0.28

* Accuracy ± 20 %
** Estimate

E = total extracts (gasoline + ether)
C = organic carbon
N = nitrogen

to slightly bluish limestone beds about 50 cm thick occur near the base of the section; a number of thinner limestone banks are found higher up.

The carbonate content of the shales, revealed by petrographic and geochemical investigation, varies considerably, and accordingly the Posidonienschiefer ranges from an almost carbonate-free shale to strongly calcareous shale or marl, apart from the limestone banks or nodular beds intercalated at a number of levels.

The content of quartz grains does not exceed about five per cent; the grains are of silt size or smaller, mostly angular and of a high sphericity. Pyrite is rather frequent in most samples in globular or framboidal form. Glauconite has not been observed in any amount except for sample no. 37 as rare accessory, and in sample no. 34 and 76 which, however, do not belong to the Posidonienschiefer. Limonite was seen in samples nos. 53 and 55. All over W Europe (except for Irlbach and a few isolated occurrences), the Posidonienschiefer is known to be poor in sand. This, together with other information, indicates a quiet marine, probably intermittently anaerobic environment (v. GÄRTNER & KRÖPELIN, 1956).

From the microscopic examination of the thin sections the organic material of the Posidonienschiefer appears to occur frequently as streaks, mainly in the carbonate-rich shales, or as uniformely distributed material. Phosphatic matter (fish remains, etc.) seems to be present in small amounts as OH-apatite. Microscopic structural bodies are common in samples nos. 57, 65, 69 and 70 and less frequent in many others; mostly these «micromorphs» are to be identified with Leiosphaeridae which show a strong luminescence under UV-light (WETZEL, 1959).

Geochemistry

The results of the geochemical analysis are given in table no. 1. The samples show fair amounts of organic carbon and extracts, the latter being the total of two solvents (gasoline and ether). The nitrogen contents are about in line with other occurences of Posidonienschiefer and so are the trace elements vanadium and nickel. The presence of substantial amounts of porphyrins with wavelength $\pm$ 570 mμ (vanadium complexes) has been observed from all samples, but the 550 mμ maxima (nickel complexes) are less pronounced and probably absent in samples nos. 47, 51 and 53.

As far as the various ratios are concerned most values are similar, except for V:Ni of the strongly calcareous sample no. 53. Generally, in bituminous rocks containing indigenous organic material, the amount of the organic matter decreases with increasing carbonate content within a given section. This probably does not hold true for all the organic material, because part of it may well be bound to clay minerals. In order to find a relationship linking the amount of organic carbon with the total extracts or taking into account the relationship's dependence on the nitrogen and clay contents various ratios have been calculated, which are given in the last two columns of table 1. The last column, giving the product of organic carbon and total extracts divided by the product of N and carbonate-free ash attempts to demonstrate this relationship: with increasing organic carbon content and extracts, the nitrogen and «clay» contents increase too.

Comparison and discussion

The Posidonienschiefer of Mont Terri exhibits an undisturbed section of bituminous shales 17 m thick at «Les Efougelles» and 19,5 m thick a few hundred metres further west at «En Méchaimé», in pit no. 7 (see RICKENBACH, 1947). As only one Harpoceras(?)

was found, a subdivision into bifrons, falcifer and tenuicostatum zone is not possible and accurate correlation with other locations thus not established.

It is, however, interesting to note the variations in thickness of the Lias epsilon and its bituminous beds in a few other areas in western Europe according to the following tabulation:

Table 2. Thickness of Lias epsilon and bituminous sequence

	1	2	3	4	5	6	7	8	9	10
a.	36	± 100	> 70	± 25	> 63	47	± 100	29	13	20
b.	17.5	25–46	> 8	> 15	± 35	36	± 60	28.5	12	19.5
c.	30	?	> 26	30*	60*	± 50**	? 130**	30**	12	19.5

a. Thickness of Lias epsilon (Lower and Middle Toarcian).

b. Thickness of main bituminous section (± «Posidonienschiefer»).

c. Bulk thickness of more or less bituminous section incl. non-bituminous intercalations.

1. Fontaneilles
2. Paris basin
3. Belleville, NW Nancy
4. Luxemburg
5. Robin Hood's Bay
6. Loon op Zand-1
7. Hemmelte West
8. Salzgitter
9. Aubächle
10. Mont Terri

* Includes part of Upper Lias delta.

** Includes part of Lias zeta.

While in central and southern France the principal bituminous section coincides more or less with the ammonite zone, characterized by *Harpoceras falcifer,* a stratigraphically extended bituminous sequence is observed to partially include the underlying tenuicostatum and the overlying bifrons zone e.g. in Luxemburg, Württemberg and Franconia. Furthermore, bituminous intercalations in the Hettangian and Sinemurian are known from many areas in western Europe; as a matter of fact, in southern England the strongest bituminous development occurs in the Lower Lias.

Comparing the stratigraphic profile of pit no. 7 (RICKENBACH, 1947) with ours of the Mont Terri section, a bed-by-bed correlation based on lithological units appears compatible with the geochemical results (table 3).

Table 3. Comparison of geochemical analysis of samples from two different Posidonienschiefer sections at Mont Terri

Samples of pit no. 7, En Méchaimé (*Kelterborn, Rickenbach,* 1947)					Samples from Les Efougelles (*A. Schneider,* 1957)				Comparison (ratios)	
Sample no.	% Moisture	Distillation products %			Sample no.	% Moisture	% Org. carbon	% Total extracts	Dist. Oil / Org. C x 1.3	Dist. Oil / Extracts
		Oil	H_2O	Gas	SCH					
h	5.0	3.8	7.6	1.0	72	3.3	8.4	0.47	0.35	8.1
g	3.8	4.2	5.0	1.4	—					
—					67	3.0	7.6	0.49	(0.43)	(8.5)
f	3.7	4.3	5.5	1.1	—					
e	3.8	3.5	5.2	2.0	60	1.9	5.8	0.42	0.46	8.3
d	4.4	5.2	7.0	1.3	—					
—					53	0.7	2.2	0.15		
—					51	3.3	12.2	0.77	(0.33)	(6.8)
c	4.4	4.8	6.1	1.8	47	3.2	9.8	0.67	0.38	7.2
b	4.4	3.0	6.6	1.2	41	2.6	6.7	0.53	0.34	5.7
a	4.5	5.1	6.4	1.8	37	3.4	5.8	0.46	0.68	11.2

Correlatable samples are thus: h and 72, e and 60, c and 47, b and 41, a and 37. From the analyses it seems that sample a and 37 are the least similar. Although our sample no. 67 does not coincide with stratigraphic position of sample g, it is practically of the same lithology; similarly, our sample no. 51 is comparable with d.

It is, of course, self-evident that the uniformity in composition of the two series of rock specimens compared with each other is not ascertained; nevertheless, the results indicate that within this section a direct relation exists between the organic carbon content and the quantity of distilled oil, a relationship already known from other sources.

In our case, the oil distilled amounts to about less than half of the organic material. Somewhat less regular are the ratios of distilled oil and extracts, indicating that an average of about eight times the extracts can be obtained by distillation.

The latter ratio values will depend to a large degree on the kind of solvents used, which in our case are gasoline and ether, but also on the way in which the distillation is carried out; in particular, the grain size to which the shale is crushed seems to be of considerable importance (see Rickenbach).

Although much more information from directly comparable analyses will have to be obtained, the above data corroborate a certain relationship between the organic matter and the oil distilled.

Of further interest appears a correlation between organic carbon content, extracts, nitrogen, trace elements, etc., and the kind of organic matter present; distillation of different bituminous rocks, the investigation of the extracts and a general comparison of chemical data with lithological and palaeontological data may reveal relationships which might throw some light on some of the still existing problems of the genesis of oil.

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