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DEEP STRUCTURAL SEISMIC REFLECTION INVESTIGATIONS ACROSS THE NORTHEASTERN STAVELOT-VENN MASSIF

by

D. BETZ, H. DURST, T. GUNDLACH

(6 figures, 1 table)

ABSTRACT.- Based on the results of reflection-seismic surveys and deep wells, the Aachen - Faille du Midi - Charriage du Condroz overthrust, after Bless *et al.* (1983), Midi overthrust, is in Ireland, England, France, Belgium and the Federal Republic of Germany considered to be an extensive nappe overthrust at the northern margin of the Variscan orogen. New scientific findings about the northern margin of the Variscan orogeny have recently aroused the interest of hydrocarbon exploration companies, who have started activities in these areas. Thus it was possible in 1985 to survey in the northeastern part of the Stavelot-Venn Massif an approximately 45 km long boundary-straddling (FRG/Belgium) deep structural reflection-seismic line in cooperation between various institutions (Federal Ministry for Research and Technology, Bonn; Belgian Geological Survey, Brussels) and industry (BEB Erdgas und Erdöl GmbH, Hannover). Due to the small geophone intervals and a 13 sec recording length, the line which runs perpendicular to the Variscan strike allows a detailed investigation of the structural style of the Variscan and Caledonian fault pattern down to the Moho discontinuity.

Vibroseis line 8501 shows in the upper part of the upper crust a dominant reflector (R1) which first dips slightly towards the SE. The reflector is interpreted to be the subsurface prolongation of the Midi overthrust. Towards the N, this horizon can be followed at a depth of approximately 2200 m in the direction of the less deformed Subvariscan Foredeep. Near Monschau, the dip of the reflector becomes steeper towards the SE. The presence of ramp-related duplex structures in the southern part of the profile is ascribed to compressive movements at a «décollement» which developed during Variscan time. Whilst the upper detachment can be related to the dominant reflector (R1), the lower detachment is assumed to be at a depth of about 7000 m in the SE prolongation of line 8501.

The indication of a structural high south of Aachen at a depth of approximately 2700 m is interpreted as the southern prolongation of the London Brabant Massif and a possible ramp for deep-seated overthrusts. The boundary between the upper and lower crust is located at a depth of approximately 19 km and shows near Monschau a flat SW-NE striking uplift. Different reflection and diffraction patterns in the lower crust with varying degrees of curvature suggest a mantle diapir which has risen from the upper mantle.

The Moho discontinuity is only visible in the southern part of the profile at a depth of 30 to 35 km as a NW dipping lamella-like zone. Further details on the complex structural inventory of the upper and lower crust are expected from the application of additional different special processing tests on line 8501.

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RESUME.- En vertu des résultats obtenus des mesures de sismique réflexion et des forages en grande profondeur la zone de chevauchement d'Aachen (Aix-la-Chapelle) - Faille du Midi - Charriage du Condroz, ou, d'après BLESS et al. (1983), plus brièvement nommé le chevauchement du Midi, est maintenant considérée en Irlande, Angleterre, France, Belgique et République fédérale d'Allemagne comme un large chevauchement de nappes à la bordure nord de l'orogène varisque. Les découvertes scientifiques récentes concernant la bordure nord du Varisque ont suscité ces dernières années l'intérêt de diverses sociétés d'exploration d'hydrocarbures. Ces compagnies ont entamé des recherches dans ces régions. c'est ainsi que dans la partie nord-est du Massif de Stavelot-Venn un profil d'exploration profonde de sismique réflexion d'une longueur de 45 km environ et franchissant la frontière belgo-allemande a pu être réalisé en 1985 en coopération entre diverses institutions (Ministère Fédéral pour la Technologie et les Recherches, Bonn; Service Géologique de Belgique, Bruxelles) et l'industrie (BEB Erdgas und Erdöl GmbH, Hannover). Grâce aux écartements étroits entre les groupes de géophones et la durée de l'enregistrement de 13 secondes, le profil orienté perpendiculairement à la direction principale varisque permet d'étudier de plus près le style structural des éléments tectoniques varisques et calédoniens jusqu'à la discontinuité de Moho.

Le profil Vibroseis 8501 montre dans la croûte terrestre supérieure un réflecteur dominant (R1) qui est d'abord légèrement en pente vers le sud-est. Le réflecteur est interprété comme la continuation du chevauchement du Midi dans la croûte terrestre. Vers le nord, au-delà de la zone connue jusqu'ici, cet horizon a été identifié à une profondeur d'environ 2200 m vers le subvarisque moins déformé. Près de Monschau la pente du réflecteur devient plus forte vers le sud-est.

La présence des structures duplex sur la partie sud du profil est attribuée à des mouvements de compression sur un niveau de décollement qui s'est formé pendant l'orogénèse varisque. Le décollement supérieur peut être relié au réflecteur dominant (R1) alors que le décollement inférieur est présumé à une profondeur de 7000 m sur la continuation sud-est du profil.

L'indication d'un anticlinal situé au sud d'Aachen (Aix-la-Chapelle) à une profondeur d'environ 2700 m est interprétée comme contrefort méridional du Massif de Londres-Brabant et comme rampe possible pour des chevauchements profonds. La limite entre la croûte supérieure et inférieure est située à environ 19 km de profondeur; elle montre près de Monschau un soulèvement plat orienté du sud-ouest au nord-est. Au-dessous de cette limite se trouve près de Monschau une série de diffractions et de réflexions, ayant des angles apparents différents, qui sont attribuées à la présence d'un diapir provenant du manteau terrestre supérieur.

La discontinuité de Moho n'est apparente que sur la partie sud du profil à une profondeur de 30-35 km. Elle se présente en forme d'une structure en lamelle avec un pendage apparent vers le nord-ouest. L'application de différents essais spéciaux de traitement additionnels au profil 8501 y présenté devra fournir des données supplémentaires sur l'inventaire structural complexe de la croûte supérieure et inférieure

INTRODUCTION

In 1985 a deep structural reflection-seismic profile of 45 km length was surveyed in the NE part of the Stavelot-Venn Massif. The survey was carried out in cooperation with the Federal Ministry for Research and Technology (Bonn) and the Geological Service of Belgium (Brussels), with BEB Erdgas and Erdöl GmbH (Hannover) as the leading partner. When planning the Vibroseis profile the following objectives were set :

- identification of the course of the Midi overthrust down into deeper strata,
- mapping of the flat reflector already known from reflection-seismic data obtained in Belgium, France, England, Ireland and the Federal Republic and whose existence has been proven in deep wells in Belgium and France. The reflector is interpreted as the most recent overthrust (thin-skinned tectonics) of Variscan orogeny. A further aim was to analyze the reflector's properties (reflection character, dip, structure, etc.) so as to
- obtain information on the geological/tectonic pattern of the near-surface and deeper strata,
- investigate the influence of the southern prolongation of the structured Brabant Massif in a possible ramp situation at the northern margin of the Variscan orogen,
- obtain information on the stratigraphic units below the reflector dipping gently towards the SE.

Besides the geological significance of more detailed information on the structural relationships in the northern Variscides, which especially in Belgium were tested by several deep wells, this profile is also particularly important with respect to improved knowledge of mineral and energy resources in the Federal Republic.

GEOLOGICAL AND GEOPHYSICAL SETTING

By any definition, the predominant structure in the northwestern part of the Rhenish Massif (RM) is the Stavelot-Venn Massif with its NE dipping crest line (Fig. 2). In the central part of this Caledonian and Variscan stressed mountain, lower Palaeozoic schistous rock series crop out over a large area. The rocks consist of quarzites and schists of the Revin (Middle and Upper Cambrian) and of the Salm (Lower to Middle Ordovician). SE of the Venn anticline the RM continues with up to 6000 m (Knapp 1980) thick, strongly folded sediments of the inner Variscan geosyncline, consisting of Lower and Middle Devonian rocks.

The Inde trough, folded and imbricated into thin-skinned thrust sheets, adjacent to the Venn anticline to the NW, contains sediments of the Namurian and Westphalian (Upper Carboniferous). Upper Devonian crops out at the southern and northern flanks of the Inde trough. Separated by a large overthrust which has been confirmed to extend as far as France (Aachen overthrust, Faille du Midi, Charriage du Condroz overthrust - designated in the following as Midi overthrust), the Wurm trough, being part of the Subvariscan Foredeep, adjoins to the NW of the Inde trough. The Upper Carboniferous sediments were subjected during the Variscan tectogenesis to a strongly NW-SE oriented compression, which particularly in the Stavelot-Venn Massif is characterized by the occurence of significant folding and faulting (Breddin 1973; Walter 1983).

Fault plane solutions of microearthquakes in the Stavelot-Venn Massif resulted in dislocation planes dipping about 10 degrees to the SE (Ahorner *et al.* 1983). These movements are due to the current seismotectonic stress field of Central Europe with NW-SE directed compression (Ahorner *et al.* 1972; Illies *et al.* 1981). The orientation coincides with the stress field acting during the Variscan orogeny. For the actual tectonic stress release the overthrust structures which developed in Variscan time are preferentially reactivated. The

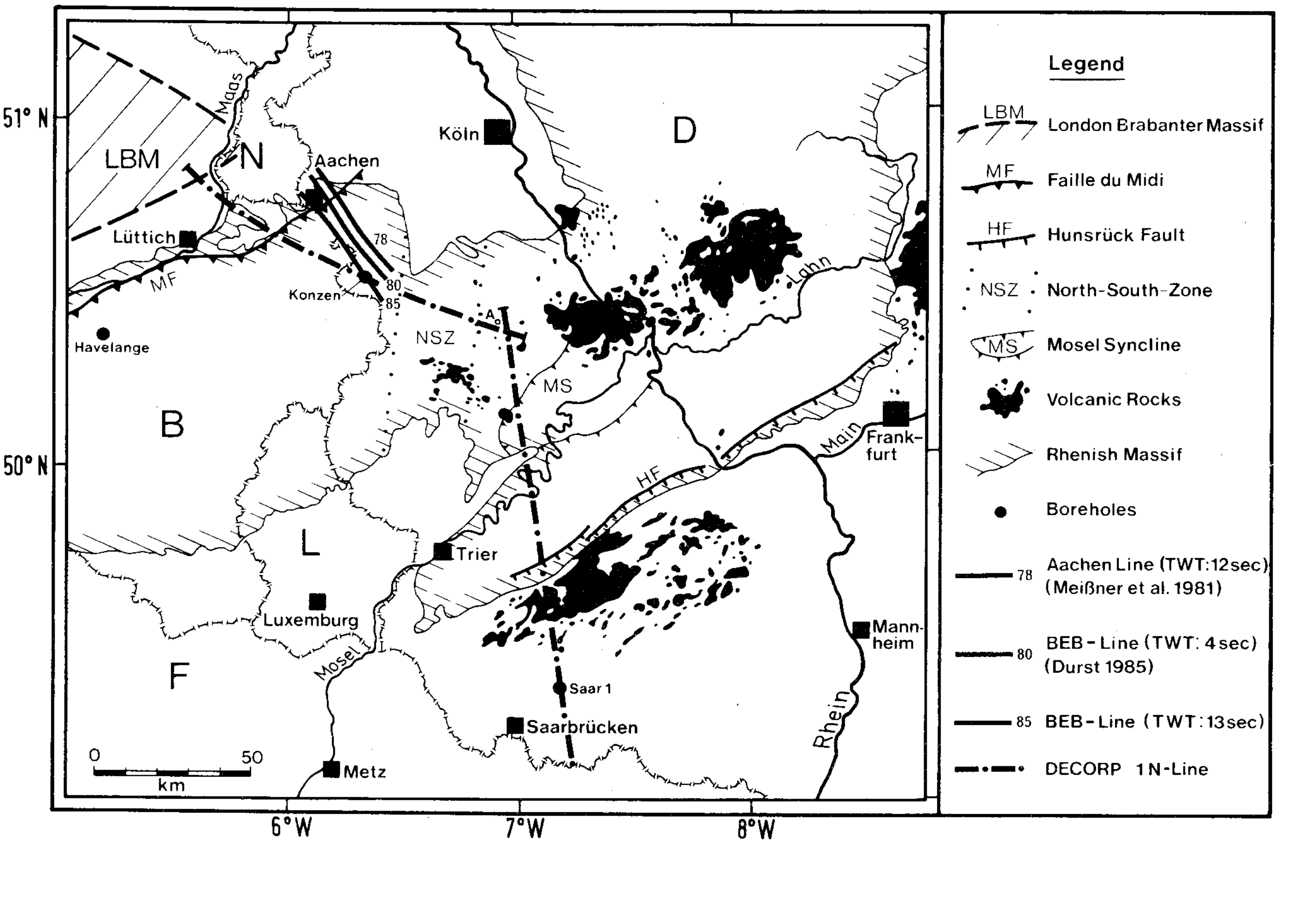

Fig. 1.- Sketch map of the Rhenish Massif and adjacent areas with location of seismic lines 8001, 8501, «Geotraverse Rhenoherzynikum» DECORP 1 N and wells Havelange and Konzen. B, Belgian; N, Netherlands; L, Luxemburg; F, France; D, Federal Republic of Germany (modified after Meißner, personal communications 1987).

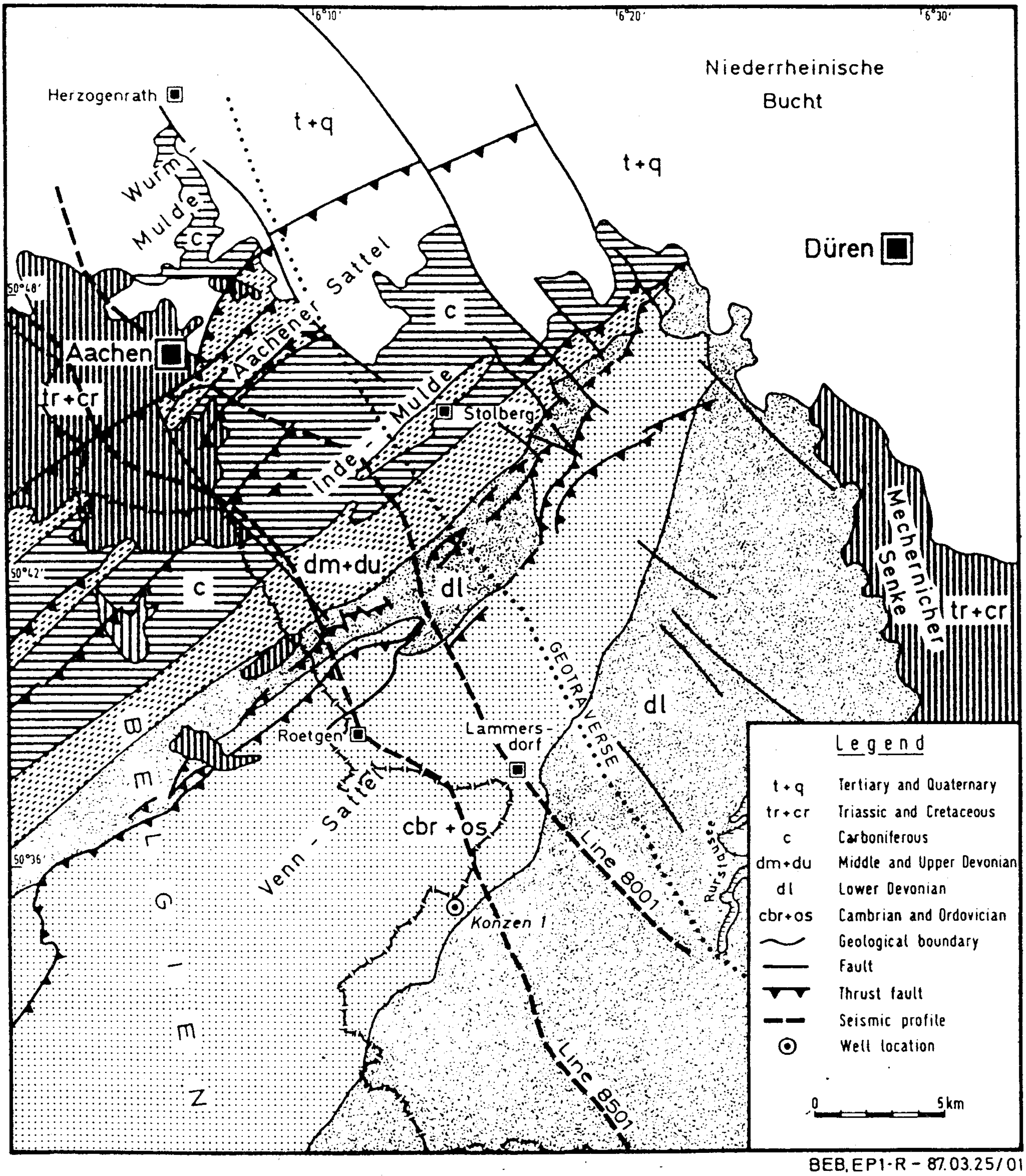

Fig. 2.- Simplified geological map of the northeastern Stavelot Venn Massif and adjacent areas with location of seismic lines 8501, 8001 and «Geotraverse Rhenohercynikum».

hypocentres of the seismicity observations going back to the year 1755 with magnitudes up to M_L 4.6 (Ahorner *et al.* 1983) which can still be observed today on a regional scale favour a lasting tectonic activity.

As early as 1963 a strong reflector dipping to the S from 2 to 10 km was confirmed in Northern France by *reflection-seismic* surveys and interpreted as the subsurface prolongation of the Midi overthrust (Clement 1963). Reflection-seismic surveys performed by Service Géologique de Belgique in 1978 in the area of Famenne, Belgium (approx. 100 km SW of Aachen) show several dominant reflection arrivals at a depth of 4.5 - 5.5 km (Bouckaert 1984). This range was tested in 1984 with the deep well «Havelange» (T.D. 5648 m), where several overthrusts in the Lower Devonian between 4.8 and 5.6 km have been drilled (Fig. 1), (Bouckaert, personal communications 1986). Velocity surveys in this well (VSP, vertical seismic profiling) have shown that the seismic-controlled reflectors are identical with the drilled overthrusts.

Besides the seismic line 8501 presented in this work, a dominant reflector was confirmed in Germany in 1978 as a result of the DFG research programme «Geotraverse Rhenoherzynikum» (Meissner et al. 1980, 1981; Springer 1982) and in 1980 by the BEB line » Hohes Venn 8001» (Durst 1985) at a depth of 3-4 km. This reflector has been interpreted as the subsurface prolongation of the Midi overthrust known at the surface (Fig. 1,2). The assumption of an overthrust at least 175 km wide at the northern edge of the Variscides derived from geophysical and geological investigations in Belgium and France has already been confirmed by several deep wells («Havelange», «Jeumont», Wépion», etc.) (Bless *et al.* 1983, Bouckaert personal communications 1986). However, no comparable deep drilling project has yet taken place in Germany.

Refraction-seismic surveys in the Hohes Venn show at a depth of about 10 km a 1-2 km thick zone of high velocity of 6.65 km/sec, underlain by a zone of decreased velocity (6.0 - 6.1 km/sec). The boundary between the upper and lower crust seems to be at about 20 km depth due to a dominant reflection. The crust-mantle boundary is presumed to be at about 33 km on account of a 2-4 km thick transition zone in which the velocity gradually increases from 6.6 to 8.0 km/sec (Prodehl *et al.* 1985).

According to the evaluation of *aeromagnetic surveys,* a strip of narrow positive magnetic anomalies runs along the Ordovician/Upper Cambrian outcrop on the southern flank of the Stavelot-Venn Massif. This is caused by a strong concentration of ferromagnetic minerals (Wolf *et al.* 1954). Iron sulphides from drilling cores and the results of magnetic well logging in the «Konzen» research well (Fig. 1,2) have confirmed this presumption to be the magnetic «anomaly of Lammersdorf» (Bosum 1985; Franken *et al.* 1985; Müller *et al.* 1985). The crystalline basement in the German part of the Stavelot-Venn Massif is, according to Bosum (in Bless *et al.* 1980b), presumed on the basis of a large-area magnetic anomaly to be at a depth of 5-10 km.

Magnetotelluric surveys performed SE of the Stavelot-Venn Massif show at a depth of about 10 km a well-conducting horizon, which is linked with a good conductor confirmed to exist at a comparable depth in the Rhenish Massif (Lohr 1982; Jödicke 1983, 1985).

By contrast with the magnetic surveys, *gravimetric surveys* carried out N of the Stavelot-Venn Massif near Eupen (Belgium) show a dominant negative gravitational anomaly. Possible evaporite occurences in the Upper Devonian and Lower Carboniferous or an acidic intrusive body are quoted as being the cause (Plaumann 1985).

FIELD SET UP AND PROCESSING

In the planning phase of line 8501, above all the experience gained by BEB Erdgas und Erdöl GmbH in the course of hydrocarbon exploration in the Hohes Venn - besides the experiences made with the public scientific projects «Geotraverse Rhenoherzynikum» and DECORP (in particular planning for the DECORP 1 N profile) - was used to determine the line and the field parameters.

Fig. 2 shows the location of line 8501 on a simplified geological map of the northeastern part of the Stavelot-Venn Massif. Line 8501 runs, like the already published profiles «Rhenoherzynikum Geotraverse» and BEB line 8001 further to the east, almost at right angles to the Variscan strike and crosses the NW vergent folded structure of the Stavelot-Venn anticline, the north-adjacent Inde trough, the Aachen anticline and the Wurm trough. The southern part of the profile includes the «Konzen» research well drilled in 1982/83 (T.D. 400m), (Fig. 1, 2). The field set up and subsequent processing were done by Compagnie Générale de Géophysique (CGG) in Paris, France. The most important field parameters are summarized in Table 1.

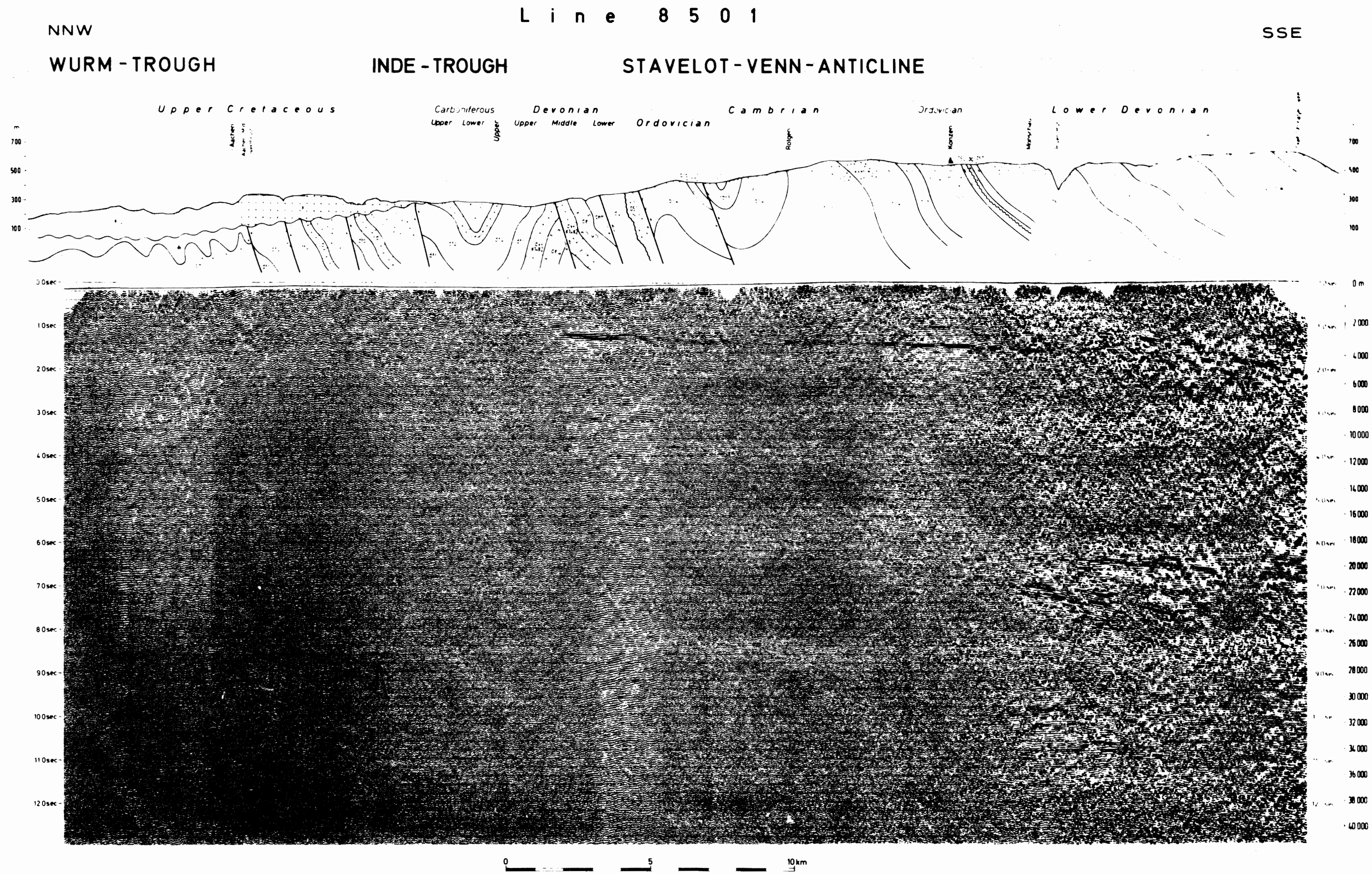

Fig. 3.- Unmigrated and uninterpreted seismic line 8501 across the northeastern Stavelot Venn Massif.

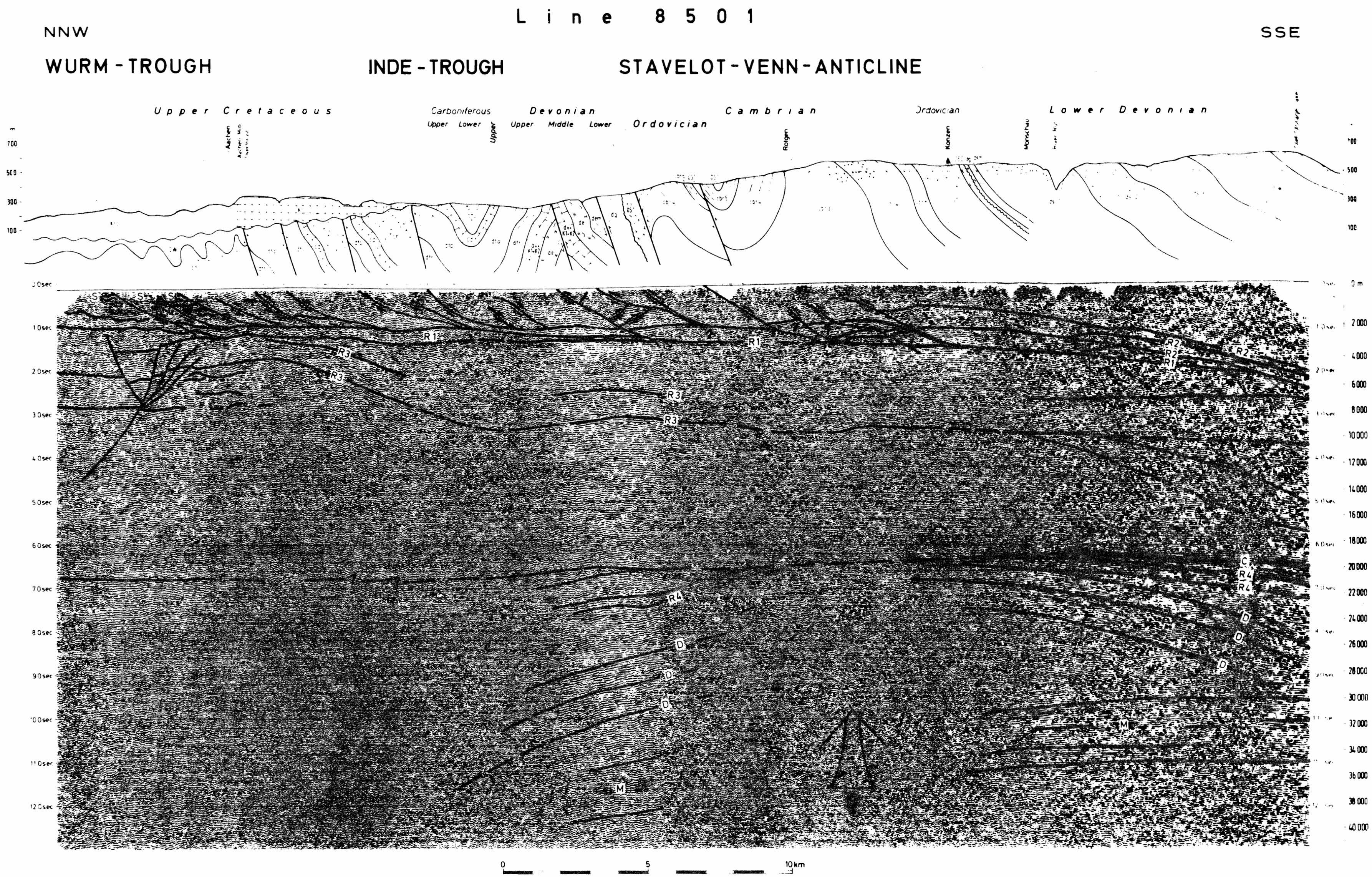

Fig. 4.- Unmigrated seismic line 8501 across the northeastern Stavelot Venn Massif. Vertical exaggeration 1 : 1.6. Visible reflectors are indicated : R1 = Aachen-Midi overthrust; R2 = possible ramprelated structure (duplex structure); R3,R4 = Anticlinal structure; M = Moho Diskontinuität; C = Conrad Diskontinuität; S = Folds; D = Diffraction.

Table 1 : Field parameters of seismic line 8501

Recording equipment :	Sercel SN 368 (without correlator)
Number of traces :	200
Group distance :	30 m
Coverage :	50-fold
Vertical stack :	8-fold
Trace configuration :	split spread
Number of vibrators :	5 (Mertz 22)
Sweep frequency :	16 - 64 Hz
Recording length :	22 + 13 sec
Sampling rate :	4 ms

In the course of the processing work in the processing centre of CGG (Paris) several pre-correlations and stacking tests were necessary in order to optimize the data material in accordance with the available reflections. Due to particularly difficult geological/tectonic conditions along the whole line, several velocity analyses had to be carried out over the entire profile to improve the dynamic corrections. After the static residual corrections had been determined and the final stacking carried out the signal/noise ratio could be substantially improved by using a so-called «noise reduction filter». The migration work has not yet been concluded.

GEOLOGICAL AND GEOPHYSICAL INTERPRETATION

In the conventional interpretation of reflection-seismic profiles, as applied particularly by exploration companies, geological formations with certain petrophysical conditions can be correlated over large distances and be stratigraphically allocated in connection with the available deep drilling information. As both prerequisites apply to the present profile only to a certain extent, particularly the geological outcrops and the results of non-seismic methods performed along the line are an important support for the interpretation.

Fig. 3 shows the unmigrated and non-interpreted seismic line 8501. Fig. 4 shows the same stack with a first attempt at interpretation. The seismic profiles are shown in a ratio 1 : 1.6 (vertical/Horizontal scale). Besides the two-way travel time (TWT) the corresponding depth values are given, based on the stacking velocities. On top of the two seismic profiles the most important geological structures (Walter, personal communications 1987) and tectonic elements as well as the topography are given together with some aids for orientation (vertical exaggeration 5 : 1). The datum level (0.0 sec line) of line 8501 is 500 m above sea level.

The dominant reflection element in the upper layers of the profile is a partly faulted horizon which can be correlated over long distances without problems. The existence of this SE dipping reflector (R1) is in particular in the northeastern part of the Stavelot-Venn Massif well confirmed by a dense seismic grid of hitherto unpublished BEB profiles. Comparable results are available from Belgium, Northern France, Southern England and Ireland concerning the western continuation of the northern edge of the Variscides (Clement 1963; Bless *et al.* 1980b; Bouckaert 1984; Bois *et al.* 1986; Meissner *et al.* 1986). The main results of the deep drilling projects in Belgium and France, the fault plane solutions of the recently measured microearthquakes and the for this area relatively strongly reflecting horizon in the seismic profiles are indicators of a large-area overthrust (thin-skinned tectonics) at 3-4 km depth, comparable with the flat overthrusts in the northern Appalachians (Cook *et al.* 1980). For the eastern continuation of the northern edge of the Variscides, neither the reflection-seismic surveys performed in 1983/84 in the Harz Mountains (Fürhrer 1987) nor the geological/tectonic investigations in the Ruhr area Wrede 1985b) could provide clues as to the overthrust model accepted for the western part. For the occurrence of differing tectonic styles in the western and eastern RM, a decisive role is played above all by the London-Brabant Massif (LBM) as a ramp and the Eifel N-S zone as a vertical detachment in the course of the Variscan orogeny (Fig. 1). While in the eastern RM the advancing Variscan deformation front could penetrate more or less unrestricted towards the north, thus rendering the creation of a décollement at a low depth unnecessary, the intense overthrust tectonics and folding in the west are caused by the fact that the LBM is relatively close to the surface. This is also shown by tectonic investigations carried out by Wrede (1987) in the Aachen-Erkelenz coal mining district, where, due to the turn of the NE-SW striking fold axes to N-S direction, the decreasing influence of the east dipping LBM on the deformation of the northern outer zone is documented.

The reflector (R1), which is interpreted as the subsurface continuation of the Midi ovethrust (Meissner *et al.* 1980, DURST 1985), at first dips flatly towards SE at an angle of about 4 degrees. It loses its character in northern direction, so that a direct connection to the overthrust which crops out at Aachen cannot be definitely confirmed by

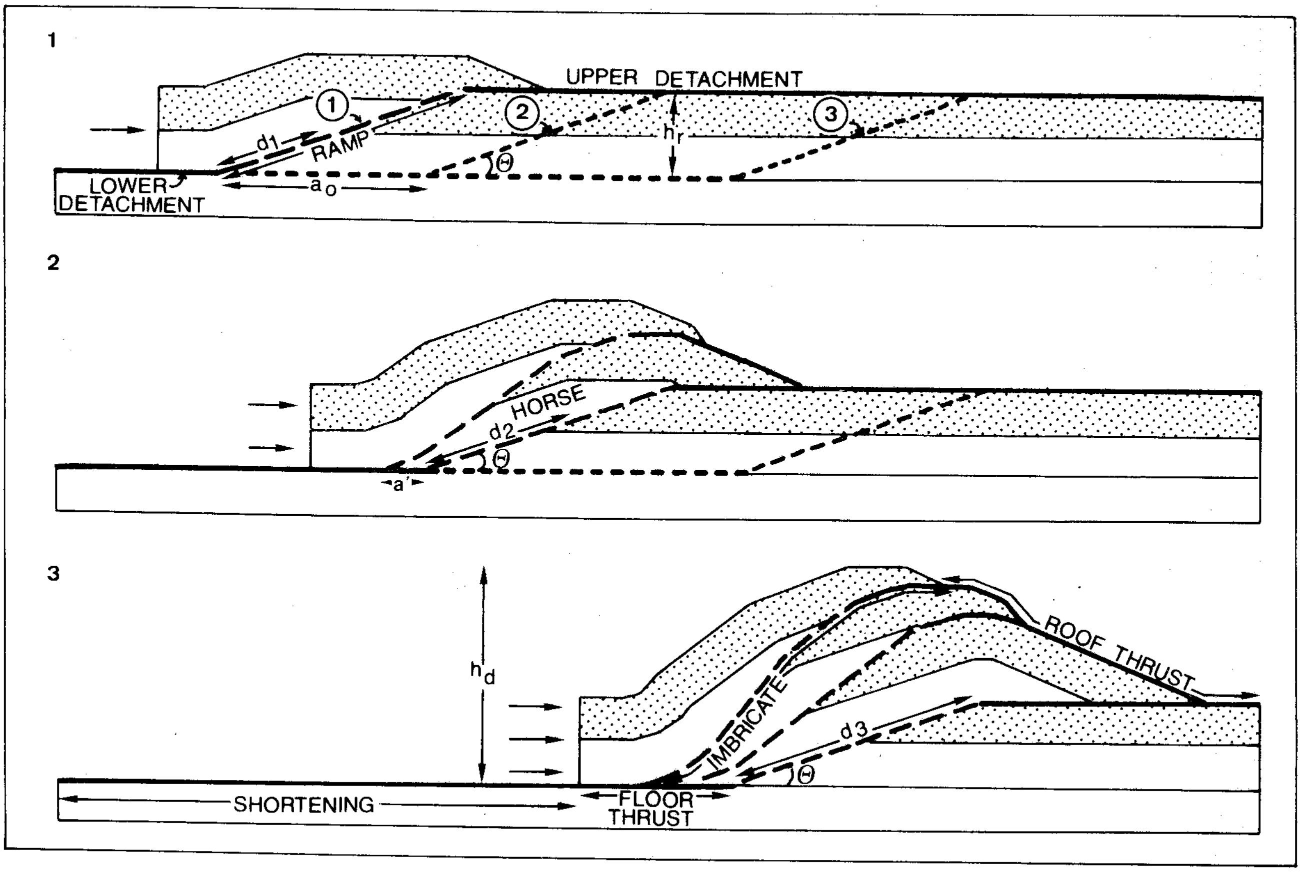

Fig. 5.- Model of foreland dipping duplex structures. Parameters controlling geometry of duplex including angle (θ) height (h_r) and initial (a_o) and final (a') spacing between adjacent thrusts. Duplex height is indicated by h_d. The terms lower and upper detachement and ramp refer to individual thrusts, whereas floor, roof and impricate thrusts refer to duplex (after Mitra 1986).

the present line 8501. Reflections from a depth of about 2000 m N of the Midi overthrust rather proved good indications of a farther than hitherto assumed continuation of the suspected overthrust into the Upper Cretaceous sediments-covered foreland. They also provided good indications of its accompaniment, especially in the northwestern part, by intensive thrust tectonics. In the seismic line 8501 these faults - which are also known from outcrops - are identified by folds (S) in the footwall block of the overthrusts.

As has already been indicated by the interpretation of BEB line 8001 (Durst 1985), the dominant reflector (R1) changes its dip angle S of Monschau also on the present line 8501 and dips towards SE at about 18 degrees. Additionally, other good reflectors are found in this area (including R2; Fig. 3, 4), some of which can be correlated as far as the Stavelot-Venn anticline. These reflection elements, which start in the S with a dip angle of about 30 degrees, flatten out gradually towards NW and then dip to the NW while progressing further.

By analogy with the work of Berger *et al.* (1980), Boyer *et al.* (1982) and Mitra (1986), reflections occuring in the southern part of line 8501 (including R2; Fig. 5) can be interpreted as duplex structures. Sediment boundaries are excluded as being the cause of the interpreted reflectors. Fig. 5 is a model-type representation of the kinematic development of a duplex stack with the relevant terminology (Mitra 1986). The geometry of these structures is defined by the ramp angle (θ), the ramp height (h_r) and the horizontal displacement (a_o-a') of adjacent imbricates (Fig. 5). Duplex structures were successfully tested by several gas finds in hydrocarbon exploration in the Canadian Rocky Mountains (Hennessey 1975; Cordy *et al.* 1977). The southeastern part of line 8501 displays comparable tectonics in the upper layers with the steeply dipping reflectors (R2) suggesting a ramp structure in the underlying strata. As is shown in Fig. 5, upper detachment might be linked with the dominant reflector (R1). There is no seismic indication so far of the lower detachment, which is assumed to be located southeast of the end of the line at a depth of at least 7000 m. The DECORP 1 N line

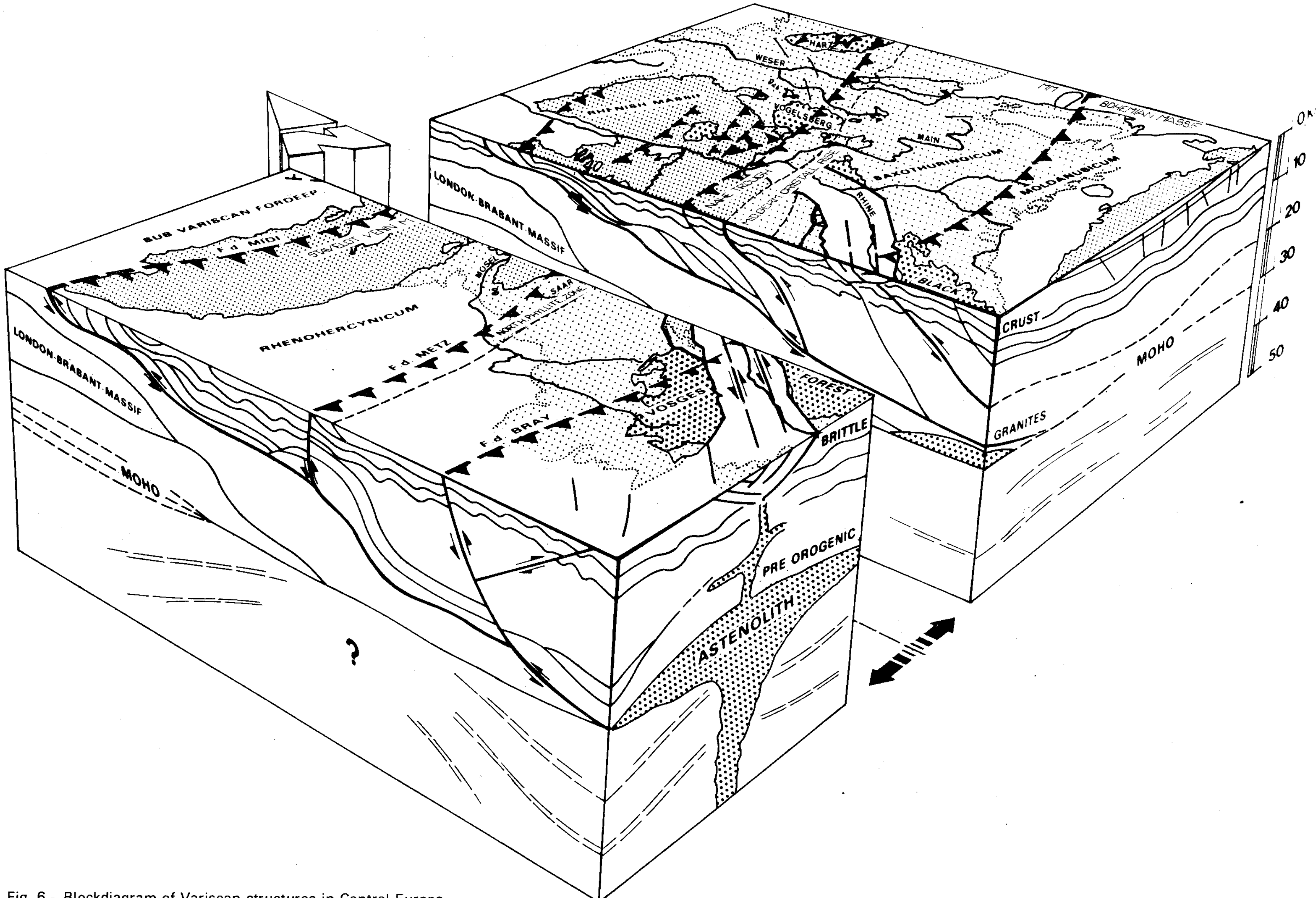

Fig. 6.- Blockdiagram of Variscan structures in Central Europa.

(Fig. 1), scheduled for 1987, which will cross line 8501 near Monschau, is expected to contribute a great deal to answering this question. North of the Stavelot-Venn Massif, the reflection seismic profile shows typical thrust belt tectonics (Walter *et al.* 1983) with a detachment propagating to the NE. The relationships described have been illustrated in the block diagram (Fig. 6).

Along the dominant reflector (R1), the seismic data reveal differences in amplitude behaviour, frequency content and the occurrence of single and multiple phase events pointing to changes in rock properties and thickness variations with respect to the reflecting medium. Initial analyses in this direction have already been carried out in connection with the interpretation of the «Geotraverse Rhenoherzynikum» profile (Meissner *et al.* 1981; Springer 1982). One important result of these investigations was to provide proof that due to a negative reflection coefficient the reflecting medium shows a smaller impedance (impedance = density × velocity) than the overlying strata. In view of missing refraction arrivals below the dominant reflector (R1), the thickness of this zone of high reflection quality is assumed to be less than 100 m. Initial polarity analyses made on the stacked version 8501 also suggest a negative reflection coefficient, which, considering the strong reflection amplitudes, points to a high contrast of impedance. In order to more closely approach the goal of improving the quality of information on material properties in the underlying and overlying layers and the overthrust zone itself, futher special investigations (1-D and 2-D modelling, amplitude and frequency behaviour, etc.) of the available seismic data are necessary. These could be supplemented by selective S-wave experiments, which may also provide valuable lithological clues.

For the strata underlying the dominant reflector (R1), line 8501 shows some structural indications, which due to two zones of poor reflection quality below the Stavelot-Venn anticline and the Inde trough could not, however, be correlated across the whole profile. The poor data quality is mainly attributed to coupling effects at transmitting and receiving stations during field surveying.

In the strata underlying the dominant reflector (R1), the upper crust shows a number of reflections which cannot be unambiguously correlated. Especially in the northern part of the profile there are several steeply SE dipping reflections (R3) near Aachen, which could be linked with the southern extension of the LBM. This massif, which was consolidated during Caledonian orogeny, could have acted during Variscan orogeny as a ramp structure for shallow (Midi overthrust) and deeper overthrust paths and could have contributed the intensive thrust tectonics apparents at the surface. The question whether the reflection (R3) can be correlated with the rather flat reflections in the southern part of the profile as shown in Fig. 4 will only be answered from future geophysical surveys in this area. The same applies to the steeply SE dipping shear plane indicated in the southern part of the line, whose root zones reach down to the lower crust.

In the southern part of the profile, the boundary between upper and lower crust is supposed to be at a depth of about 19 km. In the profile this boundary, which is also known as the Conrad discontinuity, is marked by a reflection band (C) of high quality. In the layers below the Conrad discontinuity underneath the Stavelot-Venn Massif there is a pronounced anticlinal structure (R4), which is covered by several reflections (D) with varying degrees of curvature. Similar structures at comparable depth are also shown by the stacked version of the «Geotraverse Rhenoherzynikum» profile (BEB Reprocessing 1982). As the two profiles run almost parallel at a distance of 7 km (Fig. 2), there results a NE-SW oriented strike for the anticline axis. Lateral effects in the seismic profile can therefore be excluded. Initial migration tests performed on data of the southern part of the profile have shown that the strongly curved reflections (D) can be interpreted as diffraction energy. The high-energy diffractions and the NE-SW striking anticinal structure in the lower crust might be an idication of a diapir which has risen from the upper mantle.

Moho reflections (M) are only recognized in the southern part of the profile between 9.5 and 11 sec (TWT). The NW dipping reflections indicate a lamellar-type transition from the lower crust to the upper mantle. Further details from deeper structures are expected to become available when the migration of line 8501 has been completed.

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BIBLIOGRAPHY

AHORNER, L., 1983.- Historical Seismicity and Present-Day Microearthquake Activity of the Rhenish Massif, Central Europe. *In:* FUCHS, K. (ed.): Plateau Uplift. The Rhenish Shield - A Case History, 198-221, Heidelberg. (Springer Verl.).

AHORNER, L., MURAWSKI, H. & SCHNEIDER, G., 1972.- Seismotektonische Traverse von der Nordsee bis zum Apennin. Geol. Rdsch. 61, 915-942.

BLESS, M.J.M., BOUCKAERT, J. & PAPPROTH, E., 1980a.- Environmental aspects of some Pre-Permian deposits in NW-Europe. - Meded. Rijks Geol. Dienst, 32(1), 3-13.

BERGER, P., JOHNSON, A.M., 1980.- First order analysis of deformation of a thrust sheet moving over a ramp. - Tectonophysics, V. 70,T9-T24.

BOIS, C., CAZES, M., DAMOTTE, B., GALDEANO, A., HIRN, A., MUSCLE, A., MATTE, P., RAOULT, J.F. & TORRELLES, G., 1986.- Deep seismic profiling of the Crust in Northern France: The ECORS project. *In:* Brown, L., Barazangi, M. (eds.) «Reflection Seismology: A Global Perspective», 21-30, Geodynamics Series, American Geophysical Union, Washington, D.C.

BOYER, S.E., ELLIOT, D., 1982.- Thrust systems. - AAPG Bulletin, V.66, 1196-1230.

BOUCKAERT, J., 1984.- Deep Drilling Programs in Belgium - *In:* Raleigh, C. B. Observation of the Continental Crust through Drilling I, 28-38, Heidelberg. (Springer Verl.).

BOSUM, W., 1985.- Magnetic Measurements under Use of a 3-D Drillhole Magnetometer in the Research Borehole Konzen, Hohes Venn. - N. Jb. Geol. Paläont. Abh., 171, 145-155, Stuttgart.

BREDDIN, H., 1973.- Tiefentektonik und Deckenbau im Massiv von Stavelot-Venn (Ardennen und Rheinisches Schiefergebirge). - Geol. Mitt., 12, S. 81-130, Aachen.

CLEMENT, J., 1963.- Résultats préliminaires des campagnes géophysiques de reconnaissance dans les permis de recherches «Arras et Avesnes» de l'Association Shell Française-P.C.R.B.-SAFREP - Objectifs du froage profond Jeumont-Marpent N° 1. *Ann. Soc. géol. Nord* 83, 237-241, Lille.

COOK, F.A., BROWN, L.D. & OLIVER, J.E., 1980,- The Southern Appalachians and the Growth of Continents. - Scient. American 243, 124-138.

DURST, H., 1985,- Interpretation of a Reflection-Seismic Profile across the Northeastern Stavelot-Venn Massif and its Northern Foreland. - N.Jb. Geol. Paläont. Abh., 171, 441-446, Stuttgart.

FUEHRER, F. X., 1987.- Geological Results of Recent Geophysical Investigations in the Harz Mountains (Germany). In Press.

FRANKEN, D., BOSUM, W., WOHLENBERG, J., 1985.- A Geological and Geophysical Interpretation of the Magnetic Anomaly of Lammersdorf, Hohes Venn - N.Jb. Geol. Paläont. Abh., 171, 425-440, Stuttgart.

ILLIES, J.H., BAUMANN, H. & HOFFERS, B., 1981.- Stress Pattern and Strain Release in the Alpine Foreland. - Tectonophysics, 71, 157-172.

JOEDICKE, H. & GRINAT, M., 1985.- Magnetotelluric measurements at the SE flank of the Stavelot-Venn Anticline using the remote reference technique. - N.Jb. Geol. Paläont.Abh., 171, 425-440, Stuttgart.

JOEDICKE, H., UNTIEDT, J., OLGEMANN, W., SCHULTE, L. & WAGENITZ, V., 1983.- Electrical conductivity structure of the Crust and Upper Mantle beneath the Rhenish Massif. - *In:* FUCHS, K. *et al.:* Plateau Uplift. The Rhenish Shield - a Case History: 288-302, Berlin/Heidelberg/New York. (Springer-Verlag).

KNAPP, G., 1980.- Erläuterungen zur Geologischen Karte der Nördlichen Eifel 1:100.000. - 3rd ed., 152 pp., Krefeld.

LOHR, U., 1982.- Ergebnisse magnetottellurischer Messungen im Gebiet des Laacher Sees. - Diss. Naturwiss. Fakultät Tech,. Univ. Braunschweig.

MAELZER, H., HEIN, G. & ZIPPIT, K., 1983.- Height Changes in the Rhenish Massif: Determination and Analysis. - *In:* FUCHS, K. (ed.): Plateau Uplift. The Rhenish Massif - A Case History, 164-176, Heidelberg. (Springer Verl.).

MEISSNER, R., BARTELSEN, H. & MURAWSKI, H., 1980.- Seismic reflection and refraction studies for investigating fault zones along the Geotraverse Rhenoherzynikum/Tectonophysics, 64: 59-84, Amsterdam.

-,-, 1981.- Thin-skinned tectonics in the northern Rhenish Massif. - Nature, 290: 399-401, London.

MEISSNER, R & LUESCHEN, E., 1983.- Seismic near-vertical reflection studies of the Earth's crust in the Federal Republic of Germany, first Break, Vol. 1, 2, p. 19-24, Oxford.

MEISSNER, R., WEVER, Th., DUERBAUM H.J., 1986.- The Variscan Crust from a Geophysical Point of View: Reflection Seismics. - *In:* Freeman R., Mueller St., Giese P. (eds.): European Geotraverse (EGT) Project, 93-98, European Science Foundation, Strasbourg.

MITRA, S., 1986.- Duplex Structures and Imbricate Thrust Systems: Geometry, Structural Position and Hydrocarbon Potential. - AAPG Bulletin, V. 70, N° 9, 1087-1112.

MUELLER, R., SCHREIBER, B., THOMINSKI, H.P., WOHLENBERG, J., 1985.- The Geology and the Magnetic Field of the Southeast Flank of the Stavelot-Venn Anticline between Lammersdorf and Sourbrodt-Bôsfagne (Belgium), N. Jb. Geol. Paläont. Abh., 171, 1-16, Stuttgart.

PLAUMANN, S., 1985.- The Gravity Field of the Northern Eifel and the Hohes Venn. - N.Jb. Geol. Paläont. Abh., 171, 459-467, Stuttgart.

PRODEHL, C., MECHIE, J., 1985.- Crustal Structure of the Northern Eifel from Seismic-Refraction Investigations. - N. Jb. Geol. Paläont. Abh., 171, 453-457, Stuttgart.

SPRINGER, M., 1982.- Auswertung reflexionsseismischer Messungen im Hohen Venn. - Diploma thesis; Institute of Geophysics, Kiel.

WALTER, R. & WOHLENBERG, 1983.- Kontinentales Tiefbohrprogramm der Bundesrepublik Deutchland. Zielgebiet: Hohes Venn. Unpubl. Rep., KTB - Stb 11-83: 92 p.

WOLFF, W. & HAHN, A., 1954.- Die magnetischen anomalien im Hohen Venn. Geol. Jb., 69, 71-82.

WREDE, V., 1985b.- Die Fortsetzung der Aachener Ueberschiebung nach Osten. - Eine Arbeitshypothese. - Fortschr. Geol. Rhld. u. Westf., 33: 297-306, 1 Abb., Krefeld.

-,-, 1987.- Der Einfluss des Brabanter Massivs auf die Tektonik des Aachen-Erkelenzer Steinkohlegebietes. - N.Jb. Geol. Paläont. Abh., 3, 177-192, Stuttgart.