THE POLISH SUDETES: A MOSAIC OF VARISCAN TERRANES

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Una revisión de la evolución Precámbrica (?) y Paleozoica de diferentes partes de los Sudetes polacos muestra que la cadena está constituida por zonas contiguas que han tenido evoluciones sedimentológicos y estructurales diferentes. Comparaciones con otras partes de la cadena hercínica en Europa occidental nos hacen pensar en la aloctonía de parte de estos terrenos.

Palabras clave: Zonas estructurales, Sudetes, Cadenas Hercínicas.

A review of the Precambrian (?) and Palaeozoic evolution of the various parts of the polish Sudetes shows that the belt is constituted by contiguous zones which reflect different sedimentary and structural evolutions. Comparisons of the Variscan belt, in Western Europe, allow to question the autochthonous position of some of these terranes.

Key words: Structural zones, Poland, Variscan belt.

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The aim of this paper is to present a brief summary of the geology of Sudetes (Lower Silesia: fig. 1), described in terms of terranes, including some zones of questionable setting (suspect terranes).

MORAVO-SILESIAN ZONE

It is located east of Lower Silesia and it extends into Czechoslovakia. Devonian is represented by shales and Tentaculites limestones, then by radiolarites and diabases and finally by turbidites which lasted to Namurian. By the end of Namurian, the sedimentation became paralic. It lasted up to Westphalian. During that time, the axis of maximum subsidence moved eastwards. The main deformation here is «asturian». It developed N-S open folds.

FORE-SUDETIC BLOCK AND FORE-SUDETIC MONOCLINE

Outcrops are there very scarce and poor, so that most parts of the series are known from boreholes. The two basins: Fore-Sudetic

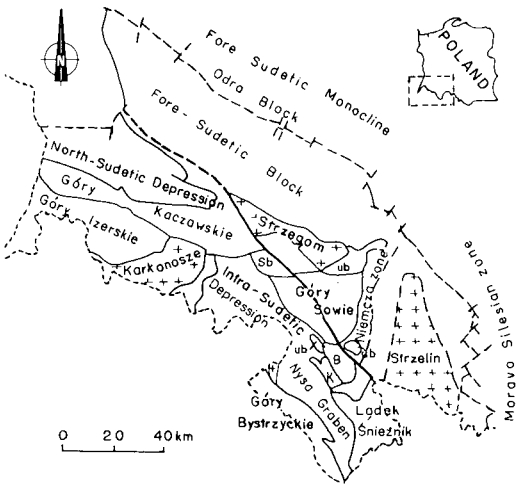

Fig. 1.—The Lower Silesia (Polish Sudetes) in Poland. S: Swiebodzice depression; B: Bardo structure; K: Klodzko massif; u.b.: mafic and ultramafic massifs around Gory Sowie.

block and Fore-Sudetic monocline, are separated by the metamorphic Odra block. This disposition recalls the German pattern, where the metamorphic mid-German crystalline rise separates the southern Saxo-Thuringian zone from the northern Rheno-Hercynian zone. The stratigraphic history of these two sudetic basins is broadly the same: shelf sedimentation during Lower and Middle Palaeozoic (Cambrian limestones and shales, Ordovician sandstones and argillites, Silurian graptolitic shales, Devonian argillites, limestones and quartzite, with Middle Devonian spilites in the foresudetic block; Culm facies: turbidites and olistostromes during Dinantian). The main deformation, here, is «Sudetic» (Oberc, 1977). The Strzegom granite has been recently studied (Puziewicz *et al.*, 1986). It yielded 278 ± 7 Ma in its western part and 323 ± 10 in its eastern part (Duthou, pers. comm., 1986).

UPPER DEVONIAN-DINANTIAN SEDIMENTARY SEQUENCES FROM GORY KACZAWSKIE TO BARDO

In the *Gory Kaczawskie,* Baranowski and Haydukiewicz (1982) described flyschtype series of Upper Visean age and Visean olistostrome including Ordovician and Devonian olistoliths. Their deposition, in the northern part of the Gory Kaczawskie, followed the main folding and metamorphic events which are thought to be Bretonian (Oberc, 1977). In the *Swiebodzice depression,* 4,000 m of Upper Devonian - Lower Tournaisian clastic sediments accumulated unconformably upon older folded strata. Paleocurrents studied by Porebski (1981) show that the clasts originated south of the depression. On the other hand, the upward coarsening of the megasequences and the increase of crystalline clasts at the top of the series suggest that the source land came nearer and nearer to the sedimentary basin during its filling. In the *Gory Sowie,* small grabens are filled by Visean terrigenous sediments which lie unconformably upon the older metamorphic series. The *Bardo depression* was active and it filled during Upper Visean and lowermost Namurian by the accumulation of conglomerates, olistostromes and turbiditic sequences. Their extremely rapid deposit in a very short time interval suggests a rapid denudation of surelevating areas combined with a strong subsidence (Chorowska and Radlicz, 1984). One has to note the presence of gabbroic and gneissic pebbles in the conglomerates.

Obviously, as stated by Grocholski (1983), horizontal movements including nappe transport and associated chaotic sedimentation have occurred from Gory Kaczawskie to Bardo, at the limit between the Fore-Sudetic basin and the Intra-Sudetic depression. The deformation of these Upper Devonian-Dinantian clastic sequences was realized either during the «Bretonian» Phase (Swiebodzice) or the Erzgebirge Phase (Bardo, Gory Kaczawskie (?)).

INTRA-SUDETIC BASIN

Its development began, after the folding of the Swiebodzice series probably as soon as Late Tournaisian, according to Grocholski (1983). 4,000 m of detrital sediments accumulated during Dinantian upon folded older series. They are represented by fluvial conglomerates and sandstones and lacustrine sediments. By the end of Upper Visean, a marine incursion deposited the clastic Szczawno formation. During Upper Carboniferous, the sed-

imentation turned from paralic to limnic conditions through the deposition of coal bearing Walbrzych, Zecler and Glinik formations. At a structural point of view, this Intra-Sudetic depression distinguishes itself from the other Carboniferous basins above described by the absence of any Carboniferous deformation, neither «Sudetic» nor «Asturian». A part of this zone is hidden beneath the Mesozoic deposits of the Nysa Graben.

METAMORPHIC ZONES OF CENTRAL SUDETES: GORY IZERSKIE, GORY KACZAWSKIE, KARKONOSZE AREA, KLODZKO AREA

Although showing some differences between them, these metamorphic zones can be presented together, owing to some important similarities in their stratigraphic and structural development. The most noticeable of these similarities are:

-i- An important volcanism and intrusive activity during Lower and Middle Palaeozoic, recognized in all of the mentioned areas: Klodzko vicinity: amphibolites and keratophyres (Kozlowska-Koch, 1960; Wojciechowska, 1966) which are dated as Devonian in the slightly metamorphosed northern part of the area, where they are associated with an Upper Silurian reefal limestone; Gory Kaczawskie series and Niedamirow: spilites, keratophyres and diabases attributed to Cambrian and Ordovician, over the Lower Cambrian Wojcieszow limestone (Teisseyre, 1980); Leszczyniec series, East of the Karkonosze granite: mainly volcanoclastic rocks, diabases and metagabbros (J. and M. Szalamacha, 1968), which prolongate in Czechoslovakia where they have been proved to represent Ordovician and Silurian.

-ii- Blueschists metamorphism characterized by the development of glaucophane (Maciejewski and Morawski, 1979).

-iii- Early Variscan (pre-Culm) age of the main deformation.

-iv- Tectonic style of this deformation, with thrust sheets (Schwarzbach, 1939; Teisseyre, 1980).

LADEK SNIEZNIK AND GORY BYSTRZYCKIE

These series comprise several highly metamorphosed units which have been considered as partly Precambrian and partly Early Palaeozoic in age (Teisseyre, 1980). Two fundamental lithological assemblages are distinguished. The Stronie Formation is composed by grey gneisses, blastomylonites, marbles with boudinaged amphibolites, leptynites and quartzites. It corresponds to the Nove Mesto Formation in Czechoslovakia. The second assemblage is composed by the fine grained Gieraltow gneisses and the augen-gneisses of Snieznik, Smulikowski (1960, 1979) showed Chet the Snieznik and Gieraltow gneisses are of the same age and origin, formed by granitization of the Stronie series. Some relics of higher metamorphic grade occur in the Gieraltow gneisses: Granulites which are thought to represent metamorphosed mafic or felsic tuffs; eclogites which form small lenticular lenses and can derive from mafic magmatic rocks.

The metamorphic history of these series is very complex. Following Smulikowski (1979), among others, three major metamorphic events are recorded: HP amphibolite facies developed with a geothermal gradient of about 18°C/km and led to granulites and eclogites. A second metamorphic event was marked by the correlative decrease of lithostatic pressure and increase of the temperature. it was responsible for the amphibolitization of the eclogites. Finally, carrying on of the temperature increase caused the migmatization of gneissic rocks. Locally it accompanied blastomylonitization processes which themselves produced the Klodzko granite.

These metamorphic phases were roughly contemporaneous with a structural evolution. Teisseyre (1973, 1980) and Cymerman (1982) described flat lying F2 shear folds refolded by open F3 folds. As pointed by Teisseyre (1980), the age of these major tectonic events is still disputable. Some workers assumed them to be Precambrian. Others, taking in account mesostructural arguments, proposed on the contrary a Variscan age. On the other hand, the Cambrian age of part of the Stronie formation favours a «Caledonian» or Variscan age.

MAFIC AND ULTRAMAFIC ROCK AROUND THE GORY SOWIE MASSIF

They constitute several massifs which are scattered respectively South, East and North of the Gory Sowie massif: Nowa Ruda, Brzeznica, Szklary and Sobotka (Maciejewski, 1968). All of these massifs display a wide variety of petrographic types. Some selected examples are enumerated below:

- serpentinites: Jordanow, Naslawice (Sobotka massif).
- gabbros and layered magmatic cumulates: Tapadla (Sobotka massif), Dzikowiec and Woliborz (Nowa Ruda massif).
- amphibolites: metadolerites showing a dike complex structure: Sobotka.
- basaltic pillow lavas: Czerwienczyce (Nowa Ruda Massif).

Each of these petrographic types has an equivalent in classical ophiolitic complexes. Therefore, even in the absence of any geochemical arguments, it is possible to assume tentatively on the basis of petrographic study that these massifs belong to a dismembered ophiolitic complex. If so, the age of its emplacement is certainly pre-Upper Palaeozoic, because pebbles of the Dziekowiec gabbro are found in the Upper Devonian conglomerates. The deformation and metamorphism of these rocks were slight.

THE GORY SOWIE MASSIF

This massif is constituted by highly metamorphosed rocks which have been compared to the Moldanubian (= inner Hercynian zone) since Kossmat (1925). The sillimanite gneisses are often migmatitic. Their initial lithologies were alternating siltstones and greywackes. Some orthogneisses are present. The above mentioned paragneisses contain various intercalations: lenticular leptynites: massive and unfoliated rocks, probably derived from felsic lavas; amphibolites: metamorphosed mafic tuffs, lavas and dolerites; crystalline limestones. Very similar complexes have been described elsewhere in the Hercynian belt, where they are called leptyno-amphibolitic group (Forestier, 1963). They characterize a «geosynclinal» environment, in a subsiding basin filled with thick flysch-like sequences and bimodal volcanic series. Alkaline granitoids (presently orthogneisses) are frequently encountered.

The first metamorphic event is recorded in relics of granulitic composition, with metastable kyanite, here and there in the gneisses. A second event was marked by the development of sillimanite. The temperature increase persisted and locally permitted a more or less complete migmatization. This metamorphic evolution (Polanski, 1955; Maciejewski and Morawski, 1979) was contemporaneous with a polyphased deformation (Grocholski, 1967). The gneissic series is affected by a polygenic foliation which was initially flat lying. The main lineation is directed NW-SE. These are contemporaneous with the migmatization processes. Open E-W structures refolded the fundamental foliation.

The limits of the Gory Sowie massif with adjacent areas are tectonic limits. In the eastern margin of the Gory Sowie, for instance, the Niemcza zone is a 4 km wide shear zone (Dziedzic, 1973). It is characterized by a tectonic mélange, post-metamorphic with regard to the Gory Sowie evolution, of gneissic material identical to the Gory Sowie series and metasedimentary rocks which are at least partially Palaeozoic.

All together, the preceeding observations suggest that the Gory Sowie zone is allochthonous, as stated very early by Kossmat (1925) and Suess (1935). If so, the Gory Sowie could correspond to the Münchberg massif recently studied (Behr *et al.*, 1982) and proved to be thrusted upon the Saxo-Thuringian zone. As in the Münchberg vicinity, the Gory Sowie thrusting can be marked in the sedimentological evolution of the Devonian and Carboniferous sedimentary basins. Besides, Bederke (1929) suggested that the Gory Sowie massif had furnished clasts to the Swiebodzice depression during Upper Devonian. The generally accepted linkage between Gory Sowie and Moldanubian series could suggest, as in Western Europe for the Moldanubian units, a Lower Palaeozoic age for its deposit and a Silurian-Devonian age for its metamorphic evolution.

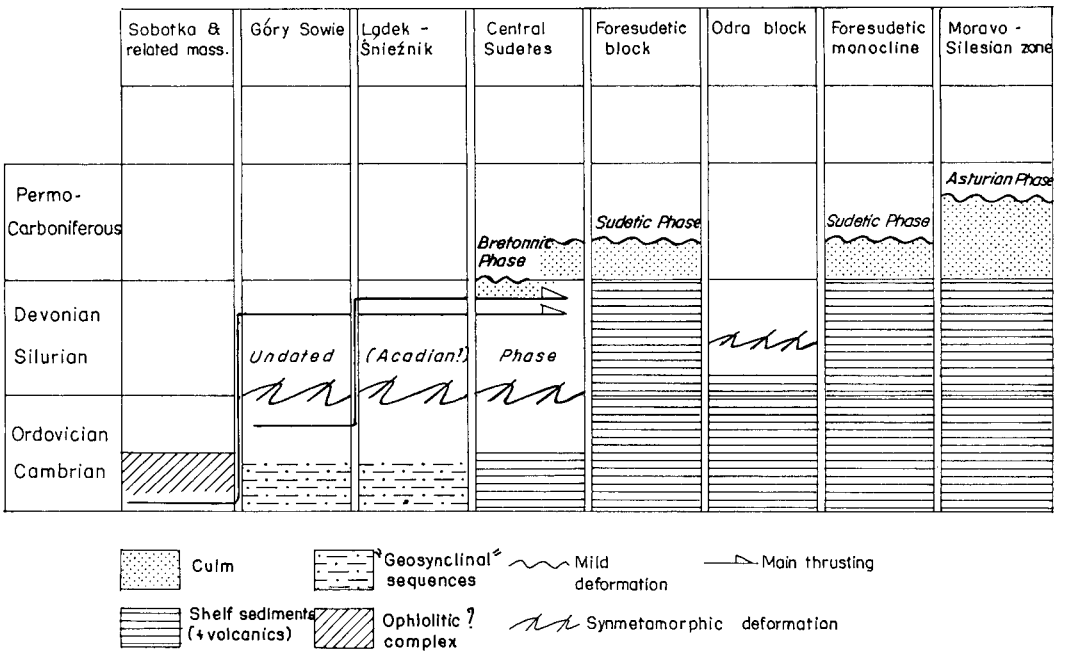

Fig. 2.–Schematic Palaeozoic evolution of the Sudetes structural zones (heavy line: Sudetic Marginal fault).

CONCLUDING REMARKS AND OPEN QUESTIONS

Obviously, the present disposition of Palaeozoic series in the Sudetes represents the result of the Hercynian composite orogeny. Hence, the full understanding of the tectonic evolution of the belt requires a palinspastic restoration of the studied terranes during the various sedimentary and metamorphic stages. Such a description is by far premature. Nevertheless, some main lines of the Sudetic orogenic development appear henceforth.

Fore-Sudetic monocline and Fore-Sudetic block are, with the *Moravo-Silesian zone,* the most external zones of the belt. Away from Poland and Czechoslovakia, they prolongate in the Variscan Externides of Western Europe: Saxo-Thuringian, Rheno-Hercynian and Subvariscan zones (Kossmat, 1927). The scarcity of the outcrops in the Fore-Sudetic block prevents to put in evidence eventual gravitary nappes such as the Harz allochthonous (Schwab, 1979). The *Central part of the Sudetes,* from Gory Kaczawskie to the Bardo structure and probably the NW part of the foresudetic block, is a composite terrane. It is constituted by Lower and Middle Palaeozoic rocks, affected by a HP (blueschist-type) metamorphism which is contemporaneous with thrust sheets or nappes emplacement. Culm series rest, with an angular discordance, upon these deformed sequences. Those which accumulated in the southern part of the Central Sudetes (i.e. Intra-Sudetic depression) remained unfolded. Those which deposited more northerly from Gory Kaczawskie to Bardo registered in their sedimentological evolution the northward progresssion of allochthonous units (Gory Sowie: see above). They were mildly deformed by bretonian and Erzgebirge phases. The *Ladek-Snieznik and Gory Bystrzyckie* represent a «geosynclinal» lithological sequence, in part of Lower Palaeozoic (Cambrian) age. During its deformation, undated till now, it has been placed in the deepest structural level of the belt and affected by a first HP (granulite facies) metamorphic episode. The mafic and ultramafic rocks of *Sobotka and other related massifs* scattered around Gory Sowie constitute a suspect terrane. They are tentatively considered as remnants of a dismembered ophiolitic complex of unknown (Lower Palaeozoic ?) age. Although their structural setting is not definitely demonstrated, they could form an allochthon-

ous slice obducted before Upper Devonian over the metamorphic sequences of Central Sudetes. *Gory Sowie* is another suspect terrane. Its lithostratigraphic sequence is similar, in many respects, to the Moldanubian terranes of Central Europe. Like the german Münchberg massif, it has been probably thrusted northwards upon the Saxo-Thuringian Central Sudetes.

Finally, the forthcoming studies in the Sudetes should have to test the following proposed succession of tectonic events (fig. 2):

1 - Upper Precambrian (?) and Lower Palaeozoic crustal distention in the South of the present belt, with the constitution of the leptyno-amphibolitic group and an oceanic crust.

2 - Lower to Middle Palaeozoic stage of resorption of the oceanic crust, with successive tectono-mettamorphic events.

3 - Rising up of the folded Southern and Central Sudetes; development of Upper Devonian and Carboniferous basins, mostly limnic in the Central Sudetes and paralic in the northern, Fore-Sudetic zones. Northward progression of the allochthonous «ophiolitic» and Gory Sowie massifs. Development of successive Erzgebirge and Asturian Phases.

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