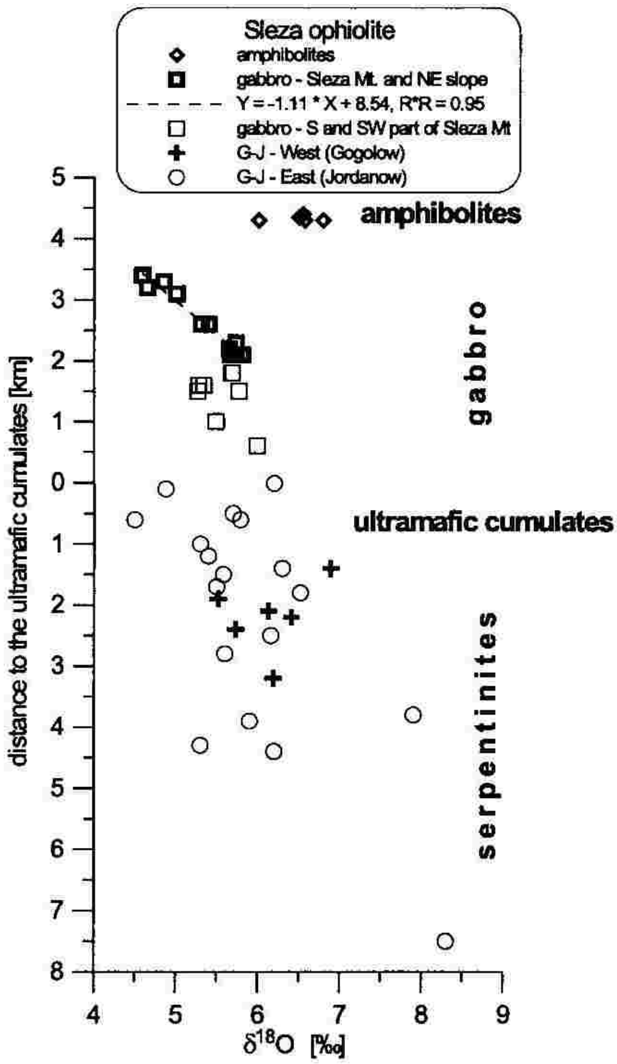

Fig. 3. $\delta^{18}O$ versus distance to the ultramafic cumulates (the potential Moho zone) of the Ślęża massif.

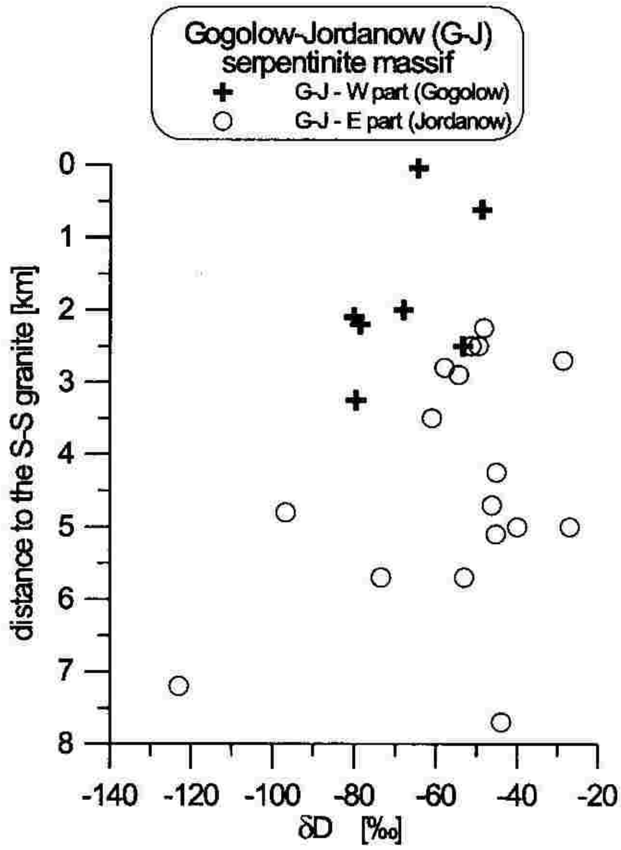

Fig. 4. δD versus distance to the contact with S-S granite massif.

Evolution of Ślęża and Nowa Ruda Ophiolites: Oceanic and Continental Stages Recorded in Stable Isotope Composition of Oxides, Carbonates and Sulphides

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Carbon, oxygen and sulphur isotope ratios in oxides, carbonates and sulphides from mafic and ultramafic rocks of Ślęża (SI) and Nowa Ruda (NR) ophiolite complexes were analysed. This was done to assess the role of ocean-floor and continental processes in ore deposit formations in these two ophiolites.

These ophiolites belong to the mafic-ultramafic massifs surrounding the significantly older Precambrian Sowie Mts. gneiss block (SM). The NR ophiolite is situated at the SW margin of the SM. Its northern part is composed of variable petrological types of altered gabbro (metagabbro) and the southern, subvolcanic part, consist of metadiabases and altered pillow lavas. The northern and southern parts are divided by the Słupiec cataclastic zone. The Ślęża ophiolite represents an almost complete ophiolite sequence comprising: Gogołów–Jordanów (G-J) serpentinite massif (ultramafic member), Ślęża Mt. gabbro (mafic, plutonic member) and Wieżyca Hill (WH) metadiabases and amphibolites (volcanic member). The ophiolite is in overturned position and the pillow lava and sedimentary members were

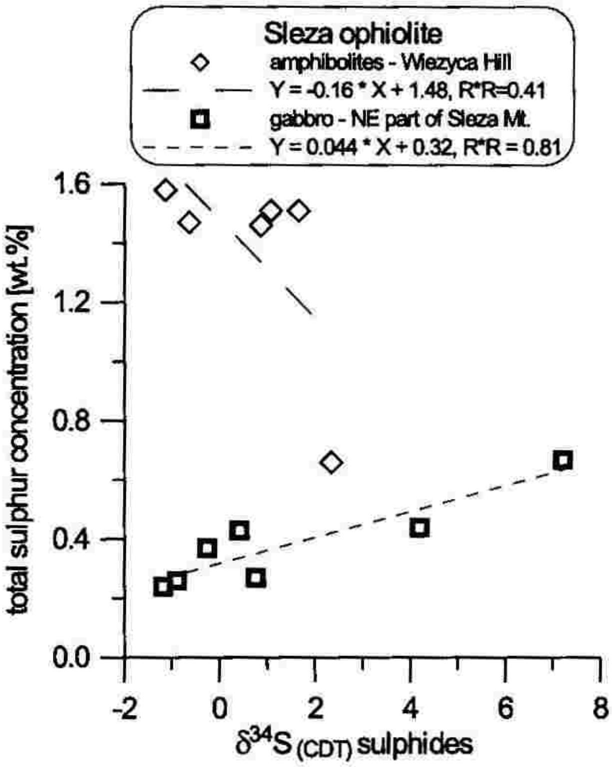

Fig. 1. $\delta^{34}S$ in sulphides versus concentration of the total sulphur in the rocks of the mafic member of the Ślęża ophiolite.

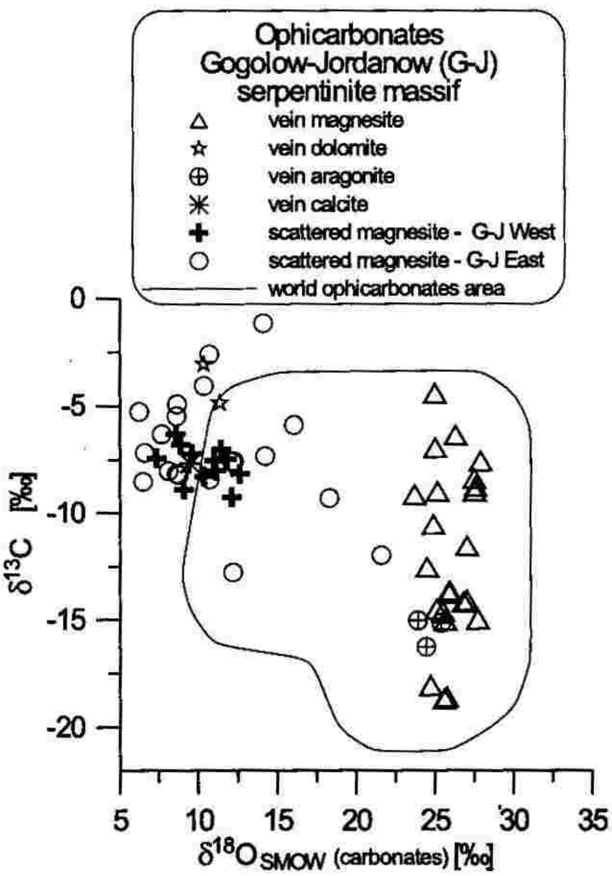

Fig. 2. $\delta^{18}O$ versus $\delta^{13}C$ in carbonates from the G-J.

not found. The Sl ultramafics lie at contact with the N margin of SM in the south, and all the Sl members lie at contact with the SE margin of the slightly younger Variscan Strzegom–Sobótka (S-S) granite massif in the N and NW. Comparison of mesostructural features of the ophiolites with such features of other Sudetic units of known age suggests that the emplacement of these ophiolites took place during the Variscan orogeny (continental collision with NE–SW suture zone, Jędrysek 1985). This assumption was confirmed by Sm–Nd age determination of the mafic member. The Sm–Nd age of the mafic member of Sl is 353 ± 21 Ma and that of NR is 351 ± 16 Ma.

The lowest whole-rock $\delta^{18}O$ value was found in the Fe–Ti-mineralised gabbro near contact with the amphibolites in the Ślęża ophiolite. In some cases a high ilmenite and magnetite content, up to 30 wt.%, is responsible for that ($\delta^{18}O$ of these minerals ranges from 3.89 to -4.44 ‰). This suggests a predominantly magmatic origin of these minerals.

Concentration of total sulphur in the Ślęża amphibolites (about 1.5 %) exceeds that expected from solubility of sulphur in mafic magma and that found in the Ślęża gabbro (0.07 to 0.67%). The $\delta^{34}S_{sulphides}$ and $\delta^{34}S_{\Sigma S}$ values ranged from -1.13 to 6.39 ‰ and from 3.33 to 7.69‰, respectively (Fig. 1). The chalcopyrite–pyrrhotite pair from volcanic member yielded the temperature of about 450 °C. Temperature obtained for chalcopyrite–pyrite pair from gabbros (plutonic member) was 112 °C. Calculations due to Rayleigh distillation model for SO_2 and H_2S degassing processes suggest at least 20 % loss of SO_2 and/or degassing of at least 56 % of H_2S, respectively. The isotope mass-balance, calculated for this model, showed that at least 4 to 23 % (or more) of all bulk sulphur is due to oceanic sulphur assimilation. The wide spread and high $\delta^{34}S$ value suggest that at least 20 % of sulphur, over that of magmatic origin sulphur, was assimilated from seawater during ocean-floor metamorphism.

Carbon and oxygen isotope ratios in GJ and NR carbonates are shown in Fig. 2 and Fig. 3, respectively. Concentrations of

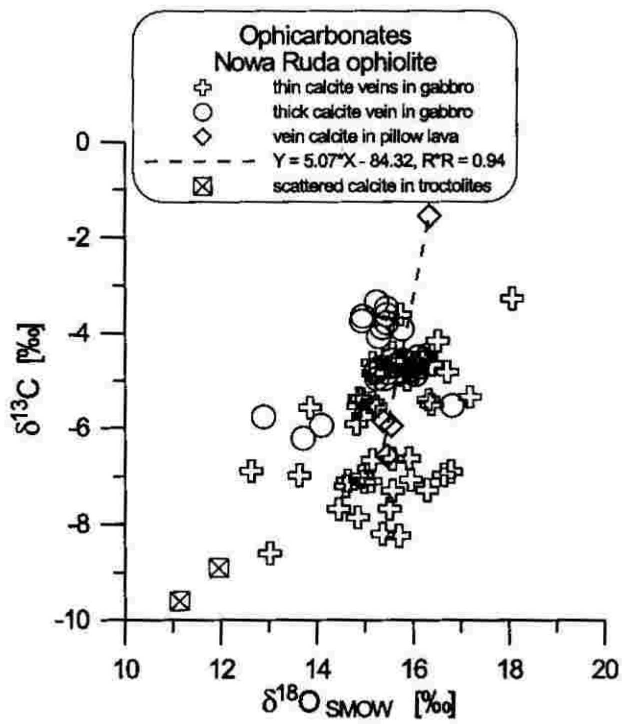

Fig. 3. $\delta^{18}O$ versus $\delta^{13}C$ carbonates from the NR.

ultramafic-hosted scattered-grain-ophimagnesites (SGOM, CO_2 yielded by decomposition of SGOM varies from 0.02 to 2.57 wt. %) and $\delta^{13}C$ (-15.99 to -1.17‰) increase and $\delta^{18}O_{SMOW}$ (6.24‰ to 25.81‰) decreases towards the centre of the G-J. These relationships possibly result from progressive precipitation of ^{13}C-poor magnesite and ^{18}O-rich serpentine minerals from external serpentinizing solutions and/or from supersaturation of that solution with CO_2 released from fluid inclusion from primary minerals of peridotite. The higher w/r ratios in the marginal parts of the GJ correlate well with structural features of the serpentinite. On the other hand, the highest $\delta^{13}C_{PDB}$ values may also result from precipitation of oceanic carbonates. This could be in agreement with NR carbonates, where the $\delta^{13}C_{PDB}$ varies in the range of -8.60 to -1.56 ‰, and the $\delta_{18OSMOW}$ values range from 12.62 to 16.80 ‰. The highest $\delta^{13}C_{PDB}$ was found in a small vein in pillow lavas, which is consistent with the assumption on a signifficant role of oceanic water in the alteration of the rocks under study. On the other hand, no correlation in $\delta^{13}C$ - $\delta^{18}O$ system was observed (Fig. 2 and 3). Moreover, in contrast to isotope values in vein magnesites from the Lower Silesian ophiolites, the transect in one 1-m wide calcite vein, oxygen isotope ratios vary much more widely than carbon isotope ratios. This may suggest that neither the temperatures nor compositions of carbon and oxygen in the mineralising fluids dominated the isotope composition of this system during the formation of thick calcite veins, but rather the most significant factor was the low temperature disequilibrium processes. On the other hand, the high $\delta^{13}C_{PDB}$ = -1.56 ‰ and $\delta^{18}O_{SMOW}$ = 16.5 ‰ of vein magnesite may suggest substantial contribution of oceanic DIC during oceanic stage of these complex and a temperature of about 110 °C for this calcite precipitation. This temperature corresponds very well to the temperature of precipitation of sulphides in the WH amphibolites.

Finally, one or two generations of oxide minerals in mafic member of the SI (magmatic and high-temperature metamorphic?), two generations of sulphide deposits (oceanic-hydrothermal and continental-hydrothermal) and 4 generations of carbonates (oceanic, continental metamorphism, contact-hydrothermal and weathering) were evidenced due to the presented results of isotope analyses.

Deformation in Front of Obliquely Moving Rigid Body

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In nature, zones accumulating transcurrent deformation are usually relatively narrow in comparison to zones exhibiting frontal deformation. We develop a model of deformation in front of obliquely moving rigid indenter producing such strain partitioning. We use two previous concepts of the deformation in a ductile viscous zone. First, approximate solutions for the velocities in the interior of a viscous sheet deformed by an indenter (England et al. 1985) show that the deformation across the zone decreases exponentially with the distance from the indenter and the transcurrent deformation has higher attenuation factor than the compressional deformation. Second, similarly as in the models of oblique transpression (Tikoff and Teyssier 1984; Thompson et al. 1997), we consider the velocity of the indenter to be split in the components parallel and perpendicular to the indenter and depending on the angle of collision. To describe deformation history in front of the indenter we consider a rock sample in the deformed zone and compute its relative velocity with respect to the approaching indenter. As the velocity of the ductile material is always lower than the velocity of the indenter, the distance of the sample to the indenter is progressively shortened. For the considered rock sample we compute temporal development of finite strain parameters – strain intensity, strain symmetry, lineation and foliation.

The model typically produces a short domain near the indenter with prevailing tangential strain followed by a wide zone dominated by compressional strain. We develop a formula expressing the distance at which the strain rate for the tangential strain rate and the compressional rate equal each other,

$$y = \frac{2L \ln[4 \cot g(\alpha)]}{3\pi\sqrt{n}},$$

where α is the angle of collision (0° for parallel and 90° for perpendicular motion), n power law exponent and L is the length of the indenter. Below this distance, instantaneous shearing parallel to the indenter boundary prevails over compression. However, from the point of finite deformation, the domain observed as dominated by simple shear is much thinner due to the more effective accumulation of pure shear type of deformation. Most interesting features of the model occur for a very oblique collision. In such case it is generally accepted that the tangential strain rate is higher than the compressional one for low angles of collision and produces horizontal lineation. Tikoff and Teyssier (1984) show that in the Sanderson's (1984) model of transpression such effect is possible for the angle of obliquity $\alpha < 20°$. In contrast to this, our model exhibits stepwise transition from horizontal to vertical lineation across the domain and it can produce horizontal lineations for angles $\alpha < 20°$.

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