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THE HISTORY OF CENTRAL AND WESTERN EUROPE

In the last years many age determinations on rocks and minerals were performed in Europe. The results add much to our knowledge of the Central and Western European continent. The Alps may be used to full effect to illustrate the meaning of age results and to show the important contribution of these data to the understanding of the development of orogenic belts.

Precambrian crystalline rocks have so far only been dated in the Bretagne (J. MICHOT and S. DEUTSCH, 1970, and F. LEUTWEIN, 1968). In the other part of Central and Western Europe the oldest ages were found by dating zircons of paragneisses. In the Alps (B. GRAUERT and A. ARNOLD, 1968, and R. T. PIDGEON, V. KÖPPEL and M. GRÜNENFELDER, 1970), zircons from paragneisses gave minimum crystallization ages of 1500 m.y. At this early time the zircons must have been formed in magmatic rocks of a continental crust. The location and composition of this old crust is unknown.

After erosion and transportation the zircons were deposited in sediments. The time of the sedimentation has been dated in several places in Europe as late Precambrian to early Paleozoic: 700 m.y. for the Villé schists, Vosges (F. LEUTWEIN, J. P. v. ELLER, J. SONET and J. L. ZIMMERMANN, 1968), 450 m.y. for the Steige schists (M. BONHOMME and G. DUNOYER DE SEGONZAC, 1962), 500 m.y. for the paragneiss from Plattas, Silvretta, Swiss Alps (B. GRAUERT, 1969).

Many rocks which were considered to belong to a Precambrian basement gave Paleozoic ages, as for example the granulites from Saxony (E. JÄGER and A. WATZNAUER, 1969). The model developed by a group of German geologists who worked in the Saualpe (Austrian Alps) may be valid not only for this area, but also for many parts of Central and

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Western Europe: The rocks from the northern and southern Saualpe represent the same series of sediments. The northern part shows a higher grade of metamorphism (kyanite schist, amphibolite) and is separated from the southern part by thrust zones and faults. In the southern Saualpe the sediments of low grade metamorphism contain enough fossils to prove the early Paleozoic age of the series. Geologists assume that the Hercynian orogeny caused the high grade metamorphism of the northern Saualpe (G. KLEINSCHMIDT, 1970, and J. NEUGEBAUER, 1970).

After sedimentation, an intensive phase of magmatic activity was dated all over in Europe: in Poland (J. BURCHART, 1970), Schwarzwald (H. KÖHLER, 1970), Massif Central (M. TOURETTE, 1967), in the Moldanubian of Saxony (E. JÄGER and A. WATZNAUER, 1969), Pyrenees (E. JÄGER and H. J. ZWART, 1968), Iberian Peninsula (H. N. A. PRIEM, N. A. I. M. BOELRIJK, R. H. VERSCHURE, E. H. HEBEDA and E. A. TH. VERDURMEN, 1970). All these rocks form an age group of 400 to 470 m.y. To the same group belong also rocks from the Alps, for example the Austroalpine units of the Silvretta and Oetztal (B. GRAUERT, 1969, K. SCHMIDT, E. JÄGER, M. GRÜNENFELDER and N. GRÖGLER, 1967, W. HARRE, H. KREUZER, H. LENZ, P. MÜLLER, I. WENDT and K. SCHMIDT, 1968), rocks from the Gotthard massif, see A. ARNOLD, 1970. Rejuvenated U-Pb ages on zircons from the Silvretta and the Gotthard massif (B. GRAUERT and A. ARNOLD, 1968) point to an intensive metamorphism contemporaneous with the plutonic activity.

This metamorphism was not detected by geologists. At this time quiet ocean sedimentation occurred in many areas in Central and Western Europe. This poses a problem: In the lower crust existed an intensive formation of magmas — whereas the ocean bottom was undisturbed, a fact which is difficult to explain until now.

All the older rocks of Central and Western Europe were strongly influenced by the Hercynian metamorphism. In the Silvretta, B. GRAUERT, 1969, determined the Hercynian metamorphism to be in the age range of 300 to 350 m.y. Orthogneisses which were metamorphosed during the Hercynian orogeny give a total rock age of 350 m.y. which dates the granite formation. The muscovite age of 300 m.y. dates the end of the Hercynian metamorphism. The Hercynian metamorphism might be nearer to 350 m.y. than 300 m.y.; however, this has yet to be proved.

After the Hercynian metamorphism occurred widespread intrusion of granites with ages of 300 m.y. and 270 m.y., followed by intensive

volcanism. Quartz-porphyrines were formed in many places in Europe 240 m.y. ago. In the Pennine area of Switzerland (J. C. HUNZIKER, 1969) and in the Tauern window (R. St. J. LAMBERT, 1964, and E. JÄGER, F. KARL and O. SCHMIDEGG, 1969) Permian quartz-porphyrines preserved the Rb-Sr total rock age of 240 m.y. The end of the Hercynian magmatic activity is indicated by pegmatite and aplite formations 220 m.y. ago (G. FERRARA, B. HIRT, E. JÄGER and E. NIGGLI, 1962; and G. N. HANSON, M. R. EL TAHLAWI and W. WEBER, 1966). Triassic plutonic and volcanic activity is also known from several places in Europe.

After a quiet sedimentation during the Mesozoic, Alpine formation began in Cretaceous time. An early, Upper Cretaceous phase of Alpine metamorphism was dated in the area SE and SW of the Tauern window (E. R. OXBURGH, R. St. J. LAMBERT, H. B. BAADSGAARD, J. G. SIMONS, 1966; and K. SCHMIDT, E. JÄGER, M. GRÜNENFELDER and N. GRÖGLER, 1967; D. S. MILLER, E. JÄGER and K. SCHMIDT, 1967). This early phase of Alpine metamorphism is also present in the Swiss Alps and seems to be a phase of rather low geothermal gradient and high pressure (phengite formation). The high pressure phase would indicate that movements preceded the metamorphic phase. The Rb-Sr total rock ages of 110 m.y. and 125 m.y., as found in the front part of Pennine nappes, might date an early phase of movement (G. N. HANSON, M. GRÜNENFELDER and G. SOPTRAYANOVA, 1969; J. C. HUNZIKER, 1969).

The next phase of Alpine metamorphism occurred at the end of Eocene and the beginning of Oligocene. J. C. HUNZIKER (1970) and E. JÄGER (1970) dated this phase at 35-38 m.y. — a result which corresponds well with the geologic evidence. This phase of Alpine metamorphism must have had a normal geothermal gradient of 30°C/km, (S. P. CLARK and E. JÄGER, 1969), and is the dominating phase of metamorphism in the Central Alps (Ticino culmination) as well as in the Tauern window. After the last phase, we found a slow uplift controlled by Rb-Sr mica ages. The uplift started at different times in different areas. It has a speed of 0.5-1 mm per year. The latest formation in the Alps are fissures with the beautiful Alpine fissure minerals with a minimum age of 10 m.y., as found in the Simplon area (E. JÄGER, E. NIGGLI and E. WENK, 1967).

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Interventi

A. Boriani: Perché pensa che l'evento datato a 400-430 m.y. non corrisponde ad un metamorfismo caledoniano anche se essenzialmente termico?

E. Jäger: I think that there is a metamorphic event, this has been shown by studies on zircons which indicate lead loss 450 m.y. ago in the Gotthard and the Silvretta gneisses.

I just want to say that we have no Caledonian orogeny, at this time we have quiet ocean sedimentation.

A. Mottana: Did you find that there are two muscovites as you found two biotites in your rocks. We have several proves that in the Schistes Lustrées of the Alps there are at least two white micas coexisting in apparent equilibrium.

E. Jäger: We did find two generations of muscovite with two different ages in one rock. The first example was the pegmatite of I Mondei which Prof. Ferrara dated. We also found phengite and muscovite of the same age in one rock.

A. Mottana: What is your opinion about Krummenacker's assumption of the existence of the Caledonian metamorphism, with high pressure rocks such as amphibolites and eclogites, in the Central Granites and Gneisses (Aar, Aiguilles Rouges, Argentera, etc.).

E. Jäger: I think that we have many indications for a pre-Hercynian high-pressure metamorphic phase in Europe, as it was postulated by Zwart. But I hesitate to correlate this metamorphism to an orogenic event. We have no indication from the field evidence for an orogeny of this time and I do not understand how to produce an enormous amount of granites and metamorphism with quiet sedimentation on the ocean floor.

P. Gasparini: Are there any laboratory experiments concerning the diffusion of Sr in minerals or the behaviour of Sr in reactions involving minerals?

E. Jäger: There are experiments, but they are not very conclusive yet. The best estimate of the activation energy of rejuvenation one gets by the slope of the rejuvenation in a distance from an intrusive body, as it was demonstrated by Hart and Hanson. The activation energy is high ~ 80 Kcal/Mole, which rather means movement of ions and reaction than diffusion.

C. Savelli: Considerando i due fattori principali nel metamorfismo ad alta pressione e metamorfismo ad alta temperatura, si può dire quale dei due influenzi maggiormente una diffusione dello Sr radiogenico e quindi determini una variazione dell'equilibrio isochimico del rapporto Rb/Sr nei minerali?

E. Jäger: We do not have much experience with the high pressure phase. I am inclined to say that high temperature does disturb isotope equilibrium more intensively than high pressure. This was demonstrated by the disturbance of the old total rock isochrone in the Pyrenees by an anatectic event. But one must remember that the rejuvenation of the front part of Pennine nappes must occur at relatively low temperature and in the presence of fluids. But generally I would think that high temperature gives more intensive changes in isotope systems than high pressure.