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UPPER MANTLE PROJECT

Final Report of Switzerland

July 1971

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INTRODUCTION

Following the recommendations of the International Upper Mantle Committee, the Swiss National Committees for the International Union of Geodesy and Geophysics and for the International Union of Geological Sciences established a joint subcommittee for the Upper Mantle Project. A first, very short, report has appeared in Report No. 3, International Upper Mantle Project (issued by the Secretariat of the Upper Mantle Committee, Los Angeles, April 1966). A second report appeared in August 1967, edited by the „Schweizerische Geologische Kommission, Basel".

Members of the Swiss Committee were: A. Gansser (Zürich), E. Jäger (Bern), H. P. Laubscher (Basel), C. Meyer de Stadelhofen (Lausanne), E. Niggli (Secretary; Bern), R. A. Sonder (Zug; until 1969), M. Vuagnat (Genève), M. Weber (Chairman; Zürich), E. Wenk (Basel).

Address of the Secretary: Prof. Dr. E. Niggli, Mineralogisch-petrographisches Institut der Universität, Sahlistrasse 6, CH-3012 BERN, Switzerland.

The activity of the committee led to greater co-operation between petrologists, geologists, geochronologists, and geophysicists.

The following special contributions from Switzerland were adopted by the committee:

1. Heat-flow in Switzerland.
2. Seismic research and scientific drilling in the Lepontine Alps.
3. Rhinegraben.
4. Combined geophysical and geological research in the Ivrea-Verbano zone.

Most of the projects have, however, not been completed. We began with *heat-flow* determinations in lakes; only provisional results are so far available (see p. 566 of this report). The geophysical research in the *Lepontine Alps* is still in the planning stage. Prof. Laubscher (Basel) participated actively in the international project "*Rhinegraben*" (see page 584 of this report). Most work has been done for the project: combined research in the *Ivrea-Verbano Zone* (sensu latissimo) (see pages 584–585 of this report). As a first step, an international symposium on the problems of this interesting zone was organized by the Swiss committee in spring 1968 at Locarno (Switzerland) and Stresa (Italy). More than 100 scientists from 6 countries attended this symposium. Following the lecture sessions, a field excursion was held. An international project was subsequently planned to measure heat flow in the Ivrea-Verbano Zone and in an adjacent region (see National reports of Germany and Italy). The symposium most definitely achieved its objectives. The Ivrea Zone is a unique element within the Alpine chain: it shows a pronounced positive gravity anomaly, a strong magnetic anomaly and a special structure of the earth's crust (the mantle coming practically to the surface). The symposium has stimulated international collaboration and scientific activity in this part of the Alps.

We would like to mention that, besides the special plans of the committee, several scientists undertook independent investigations related to the aims of the Upper Mantle Project. Research was pursued in the following fields: gravity research; geomagnetism; geothermics; tectonics; isotopic studies (incl. age determinations), radioactivity of rocks, regional metamorphism; ophiolites; eclogites; and other subjects.

During the Congress of the International Union of Geodesy and Geophysics in 1967 in Zurich two excursions were organized by the Swiss committee. The program of the first excursion (led by Prof. E. Niggli and Dr. Tj. Peters and others) mainly covered exposures of ultramafic rocks in several parts of the Alps. The second excursion (led by Prof. H. P. Laubscher) visited classical localities of Alpine tectonic structures.

GRAVITY

Prof. F. Gassmann, W. Fischer and **N. Huonder** (Institut für Geophysik der Eidgenössischen Technischen Hochschule, Zürich, Schweizerische Geodätische Kommission und Schweizerische Geotechnische Kommission, Zürich).

In 1953/54 the Swiss Geodetic Commission established a gravity base network. The gravity value at the base station in Zurich was defined by interconnection with the adjacent stations Mulhouse, Donaueschingen, Feldkirch and Milano. The instrument scale factor was determined on the French calibration line Paris-Châtellerault-Toulouse, Bagnères de Bigorre („Astronomisch-geodätische Arbeiten in der Schweiz", 25. Band, Wabern bei Bern, 1959).

Measurements for a first order gravity network have been carried out between 1962 and 1966 with a main station density of approximately 1 station per 200 km^2 with the exception of the canton of Wallis, where measurements have not yet been made. The measured values are still being processed, definite gravity values are not yet available. Preliminary results are given in: „Procès verbal de la Commission géodésique suisse", Neuchâtel 1963–1967.

This network should be completed by increasing the station density up to about 1 station per 20 km². The Geophysical Institute of the University of Lausanne and the Swiss Federal Institute of Technology are cooperating with the Swiss Geotechnical Commission in the establishment of a second order gravity network.

A special program includes bulk density determinations by several methods in order to obtain the usual corrections. Rapid changes of density result from complicated geologic phenomena. The density values are displayed on a map (unpublished reports to the Swiss Geotechnical Commission 1963–1967).

In the western Swiss Plateau 18 determinations have been carried out in the years 1963 and 1964 by Nettleton's method. Similar activity is now concentrated on the eastern Swiss Plateau. In order to complete the results obtained by the time-consuming Nettleton method additional density determinations are being made on carefully selected rock samples. Since calculations are still being processed, results are not yet published. All gravity measurements have been performed by Worden gravity meters.

In order to check the existing gravity networks in Switzerland, the Swiss Geodetic Commission has established in 1968 a control network, using three different La-Coste-Romberg gravity meters. This control network includes 75 selected stations of the funamental gravity network and the first order gravity network. At the same time, 10 stations in the canton of Wallis were determined. In addition, the Swiss gravity network has been connected with the absolute gravity station of Sèvres (Paris) in 1969. The results of these measurements are not yet published.

GEOMAGNETISM

Dr. N. Pavoni (Institut für Geophysik der Eidgenössischen Technischen Hochschule, Zürich).

Interpretation of the magnetic anomalies southwest of Vancouver Island

The investigation is based on the excellent magnetic anomaly map, published in 1961 by A. D. Raff and R. G. Mason, which covers an area off the coast of California, Oregon and Washington between 40° and 50° north latitude and 124° and 136° west longitude. A detailed tectonic interpretation of the magnetic anomalies shows that in the surveyed area, the oceanic crust is cut by seven major dislocation zones which divide the region in eight areas. For five of these areas the original connection can be reconstructed. On four dislocation zones a left lateral horizontal displacement of respectively 26, 52, 73 and 75 km is indicated. The Sovanco Fault zone SW and S of Vancouver Island shows a left lateral displacement of about 140 km. The existence of a "window" of young crust surrounded by older crust and of a short, isolated length of active oceanic ridge SW of Vancouver Island (Juan de Fuca ridge) as proposed by J. T. Wilson (1965) is not confirmed. In the area under discussion the oceanic crust originally belonged to one crustal unit which was later dissected by transcurrent faulting. The geometric relations and tectonic considerations suggest that the north-south anomalies on the "crest" of the proposed Juan de Fuca ridge are older than one million years.

Literature

N. Pavoni (1966): Tectonic interpretation of the magnetic anomalies southwest of Vancouver Island. Pure and Applied Geophysics, *63*, 172–178.

GEOTHERMICS

Prof. K. J. Hsü and **co-workers** (Geologisches Institut der Eidgenössischen Technischen Hochschule, Zürich).

Heat Flow in Swiss Lakes

A long range project to study the heat-flow of the Swiss Lakes was initiated in 1968. So far we have been assembling the necessary equipment and carried out some reconnaissance studies.

Aside from a portable research vessel and all necessary attached instruments, we have also purchased a 1.8 meter long heat-flow probe from the German Geological Survey. This short probe was first tested in Lake Zurich in 1969, where we obtained unusually steep sub-bottom temperature-gradients. The heat flow values would be twice or three times the normal value if such gradients should represent the steady state values. To resolve this question and to further explore the reliability of this type of short-probe, K. J. Hsü carried out a co-operative project with R. von Herzen of the Woods Hole Institution of Oceanography in 1970. We constructed a 7-meter probe which could measure the sub-bottom temperature gradient, but not thermal conductivity, in situ. Measurements were made in Lakes Zurich, Zug and Lucerne, and we found that the sub-bottom geothermal gradients, down to 3 or 4 meters depth, deviate significantly from linearity. The apparently steep gradients registered by the 1.8 m probe represent a transient state in response to annual bottom-water temperature changes. Under the circumstances, it seems obvious that we cannot use the 1.8 meter probe to make heat-flow measurements in Swiss Lakes. In fact, we seriously question the reliability of published heat-flow data from other European Alpine lakes obtained using this type of short heat-flow probe ($<$ 2 m long).

Unfortunately, the existing 7-meter probe cannot measure the thermal conductivity of sediments in situ. Our work also revealed the difficulty of making reliable laboratory measurements of thermal conductivity; sediments retrieved from deep lake bottoms tend to lose their dissolved gas content, resulting in the formation of numerous air or gas pockets throughout the cores. Values of thermal conductivity of those cores as determined by laboratory measurements are on the average 20% less than those made in situ by using the short probe.

Thus, after two and a half years of reconnaissance studies, we come to the sad conclusion that existing equipment is inadequate for making reliable heat-flow measurements in Alpine lakes. We are now constructing a 10-meter long probe that is capable of making *in situ* thermal conductivity measurements. P. Finckh is now working full-time on this project for his doctoral dissertation and we expect to get our first results in two years.

Prof. E. Jäger and **co-workers** (Mineralogisch-petrographisches Institut der Universität Bern, Sahlistrasse 6, Bern).

Geothermics of the Alps

Young, Alpine Rb-Sr ages on biotites give the time of cooling to 300°C after the last intensive phase of Alpine metamorphism. Rb-Sr ages on muscovites from areas of high grade metamorphism give the cooling to 500°C, Rb-Sr ages of phengites and muscovites from low grade metamorphic rocks give the time of the mica formation.

Thus the distribution of young mica ages gives information on the cooling history of the Central Alps. Based on this information and heat-flow measurements, a simplified model of tectonic and denudation history of the Alps was developed and incorporated in a quantitative theory. Near-surface geothermal gradients were assumed to be either normal or somewhat higher than normal at the peak of metamorphism; some constraints are provided by the mineralogy of the metamorphic rocks. Present heat flow emerges as a consequence of the model and thus provides a condition that must be satisfied. The most likely rate of denudation is between 0.4 and 1.0 mm/yr. Denudation accounts for 30 to 50 percent of the present heat flow.

Literature

SYDNEY P. CLARK, JR. and E. JÄGER (1969): Denudation Rate in the Alps from Geochronologic and Heat Flow Data. Amer. J. Sci. *267*, 1143–1160.

Dr. L. Rybach (Institut für Kristallographie und Petrographie der Eidgenössischen Technischen Hochschule, Zürich) in collaboration with **Prof. H. R. Wenk** (University of California, Berkeley) and **Prof. E. Wenk** (Mineralogisch-petrographisches Institut, Universität Basel).

Determination of heat production rates in Alpine rocks

For geothermic studies (e. g. interpretation of heat flow measurements) the knowledge of radiogenic heat production rates is necessary. Heat production (μcal/g, yr) in rocks is calculated from uranium, thorium and potassium abundances measured by gamma ray spectrometry (RYBACH, 1971).

Heat production rates have been determined in representative rock types from the Central Alps (for sample description see WENK and WENK, 1969). The values found in these rocks vary, in contrast to their thermal constants (i. e. diffusivity and heat capacity), over several orders of magnitude: from 0.03 μcal/g, yr (garnet-olivine-rock from Val Gnosca) to 55.0 μcal/g, yr (syenite from Val Giuv).

Publication of the results, together with results of elastic wave propagation measurements, is in preparation (WENK and RYBACH, 1971).

Literature

L. RYBACH (1971): Radiometric techniques. In: R. E. Wainerdi and E. Uken (editors): Modern Methods of Geochemical Analysis. Plenum Publ. Co. New York, 271–317.

L. RYBACH and J. A. S. ADAMS (1966): Automatic analysis of U, Th and K in solid rock samples by non-destructive gamma ray spectrometry. Proc. Int. Anal. Conf. Budapest II, 323–330.

L. RYBACH, J. VON RAUMER and J. A. S. ADAMS (1966): A gamma spectrometric study of Mont-Blanc granite samples. Pure and Applied Geophysics *68*, 153–160.

H. R. WENK and L. RYBACH (1971): Physical constants of Alpine rocks II: elastic wave velocities and radiogenic heat production rates (in preparation).

H. R. WENK and E. WENK (1969): Physical constants of Alpine rocks (density, porosity, specific heat, thermal diffusivity and conductivity). SMPM*) *49*, 341–357.

Prof. H. R. Wenk (at present Berkeley, California).

Physical Constants of Alpine Rocks (Density, Porosity, Specific Heat, Thermal Diffusivity and Conductivity)

Physical constants of 110 Alpine rocks are given. They include density, heat capacity, porosity, thermal diffusivity (with special regard to the anisotropy in

*) SMPM = Schweiz. Mineralogische und Petrographische Mitteilungen.

different fabric directions). Most of the samples were collected in the Lepontine area which was subjected to a Tertiary metamorphism.

Literature

H. R. Wenk and E. Wenk (1969): Physical Constants of Alpine Rocks (Density, Porosity, Specific Heat, Thermal Diffusivity and Conductivity). SMPM *49*/2.

TECTONICS; EVOLUTION OF THE ALPINE GEOSYNCLINE

Prof. A. Gansser (Geologisches Institut der Eidgenössischen Technischen Hochschule, Zürich).

Study of deep-seated tectonic trends

The investigations on the important Insubric (Tonale) Line are continuing. Indications for a pre-Alpine outline of this structure seem to exist. Most important are the relations of this structure with Alpine and pre-Alpine metamorphism.

Literature

A. Gansser (1968): The Insubric Line, a Major geotectonic Problem. SMPM *48*/1.

Prof. H. P. Laubscher (Geologisches Institut der Universität Basel, Bernoullianum, Basel).

Alpine Orogenesis

Fundamental problems of Alpine orogenesis have been studied by H. Laubscher, and the following publications are the result of his efforts:

Literature

H. P. Laubscher (1969): Mountain Building. Tectonophysics *7*/5–6.
— (1970): Das Alpen-Dinariden-Problem und die Palinspastik der südlichen Tethys. Geol. Rdsch. *60*.
— (1970): Bewegung und Wärme in der alpinen Orogenese. SMPM *50*/3.
— (1971): The large-scale kinematics of the Western Alps and the Northern Apennines and its palinspastic implications. Amer. J. Sci.
— (1971): Jura mountains and gravity sliding. To be published in "Gravity tectonics".

Dr. N. Pavoni (Institut für Geophysik der Eidgenössischen Technischen Hochschule, Zürich).

a) Regularities in the arrangement of oceanic ridges

The investigation is based on the distribution of epicenters of earthquakes along the crest of active oceanic ridges. The epicenters of about 700 earthquakes that occurred from 1953 to 1965 given by J. P. Rothé (1969) were used for computation. Two hypothetical centers, near 170°W/0°N (Pacific Center) and near 10°E/0°N (African Center), were determined from which the distribution of epicenters reveals some remarkable regularities. As to these centers 71% of all the epicenters are arranged in distinct, either latitudinal or longitudinal sequences. Accordingly latitudinal and longitudinal ridges and fracture zones may be distinguished. In the Pacific area the latitudinal sequences lie on a semicircular zone in 60–70 degrees distance from the Pacific Center. On the other hand, the epicenters e. g. of the Galapagos ridge, Chile ridge, Mid-Indian ridge/southeast branch are situated on distinct longitudinal strips. As to the African Center, the arrangement of epicenter-is complicated by the break-up of Gondwanaland. Nevertheless, the majority of latitudinal sequences are situated in a circular zone 50–60 degrees, in the Norths Atlantic up to 72 degrees away from the African Center.

The Pacific and African Center as poles define a spherical system of coordinates which shows a remarkable relation to Cenozoic tectonics. The proposed regularities in the arrangement of oceanic ridges are not in contradiction with plate tectonics but may constitute a deep-seated frame for the arrangement and boundaries of the plates. As to the two hypothetical centers the African plate and the Pacific plate are homologous plates.

Literature

N. Pavoni (1969): Zonen lateraler horizontaler Verschiebung in der Erdkruste und daraus ableitbare Aussagen zur globalen Tektonik. Geol. Rdsch. *59*/1, 56–77.

— (1970/71): Gesetzmässigkeiten in der Anordnung ozeanischer Rücken. Umschau in Wissenschaft und Technik *9*, 318–319.

b) Investigation of the recent horizontal movements of the earth's crust

Compilation and interpretation of data on active strike-slip fault zones, i. e. strike-slip fault zones which show movement during the Holocene, and kinematic analyses of Cenozoic tectonics, show that, in principle, the present horizontal movements of the crust may be considered as a direct continuation and development of Cenozoic horizontal tectonic movements. The large scale regularities in the arrangement of active and Cenozoic strike-slip fault zones point to the fact that large portions of the earth's crust within the Alpide fold belt undergo more or less uniform horizontal deformation. An attempt was made to trace on a world map a hypothetical net of shear lines in such a way that – with regard to the sense of displacement – the directions of the shear lines would coincide with the strike of active and Cenozoic strike-slip faults. The shear net shows remarkable symmetries and homologies. For example, a "center" is indicated in Central Africa, a second one, 180 degrees of longitude away in the central Pacific. The directions of maximum horizontal pressure as derived from the shear net would be consistent with (1) a movement of mantle material away from these "centers" towards the Alpide fold belt and (2) a slow counterclockwise rotation of the Gondwana area and the Pacific area.

Literature

N. Pavoni (1964): Aktive Horizontalverschiebungszonen der Erdkruste. Bull. Ver. Schweiz. Petrol.-Geol. u. -Ing. *31*/80, 54–78.

— (1966a): Recent horizontal movements of the earth's crust as related to Cenozoic tectonics. Proc. Second Int. Symposium on the Recent Crustal Movements, Aulanko, Finland, Aug. 1965. Ann. Ac. Sci. Fenn. Ser. A, III. *90*, 317–324.

— (1966b): Investigations on the stress state of the earth's crust: Evidence from active wrench faulting. Trans. Amer. Geophys. Union, *47*/1, 177.

— (1967): Ruhelose Erde. Schweizer Illustrierte Nr. 41, 64–75.

— (1971): Recent and late Cenozoic movements of the earth's crust. Proc. Int. Symp. Recent Crustal Movements and Ass. Seismicity, Wellington, New Zealand, Febr. 1970, Royal Soc. NZ., Bull. *9*, 1–11, Wellington (in press).

Prof. R. Trümpy and **co-workers** (Geologisches Institut der Eidgenössischen Technischen Hochschule und der Universität, Zürich).

Sedimentary and paleotectonic evolution of the Alpine geosyncline

Critical areas which were tested for their bearing on the paleotectonic development of the Alpine geosyncline include:

1. Lower Cretaceous of Helvetic miogeosyncline. An important work by H. P. FUNK („Zur Stratigraphie und Lithologie des Helvetischen Kieselkalkes und der Altmann-Schichten in der Säntis-Churfirsten-Gruppe (Nordostschweiz)") has just been completed and is now in press. One of the aims of this work was to gather further data on cyclic sedimentation and subsidence in the miogeosynclinal belt on the northern margin of the Alps. The results are partly negative, in the sense that the glauconite-shale-limestone cyclothems are far less regular than it was classically supposed. The question of the control of cyclic sedimentation – tectonic vs. climatic control or the combination of both (upwelling of cold water) – is still open.
2. A working group has started systematic investigations on submarine scarp breccias along one of the hinge lines, south of the Piemont eugeosyncline. It is hoped that a better understanding of the sedimentation mechanisms, the paleotectonic and bathymetric situation, can be gained and that this may give a clue for the interpretation of Alpine eugeosynclines in comparison with present-day models.

R. Trümpy has discussed the possible evolution of the crust in the Alpine geosyncline during the pre-orogenic phase. His conclusions are that the stratigraphic development of the Alpine geosyncline can be easily understood by assuming processes of crustal reduction (oceanization) but that it is much more difficult to reconcile the evolution of the geosyncline with ocean-floor spreading according to the present Atlantic model. The uniform distribution of continental, then shallow marine sediments preceding the onset of geosynclinal subsidence seems to be an essential point.

More recently, R. TRÜMPY has tried to assemble the stratigraphic and radiometric data concerning the times of deformation in the Swiss Alps. Compressional movements seem to be spasmodic rather than continuous and to proceed at very fast rates (2–6 cm/year). The paper ("Timing of orogenic events in the Central Alps") will appear in the volume "Gravity and Tectonics".

Literature

R. TRÜMPY (1971): Stratigraphy in mountain belts. Quart. J. Geol. Soc. London, *126*, 293–318.

ISOTOPIC STUDIES (INCL. AGE DETERMINATIONS)

Prof. M. Grünenfelder, Prof. P. Signer and **co-workers** (Laboratory for Isotope Geology and Mass-spectrometry, Swiss Federal Institute of Technology, Zürich).

Potassium-Argon age determinations have been performed to unravel the post-Hercynian history of the Ivrea-Verbano Zone, thought to contain elements of upper mantle origin (F. McDOWELL and R. SCHMID, 1968) and of the adjacent regions within the Southern Swiss Alps (F. McDowell, 1968 and 1970). U-Pb ages of zircon suites of a variety of metasedimentary and granitic rocks in the Southern Alps indicate a major event at 430–500 my. as well as Precambrian crystallisation as old as 2.500 m.y. (R. T. Pidgeon et al., 1968 and 1970). U-Pb and Rb-Sr age determinations have been performed on a variety of igneous and metamorphic rocks within the alpine orogenic belt of the Swiss Alps (B. Grauert and A. Arnold, 1968; B. Grauert, 1969; G. N. Hanson et al., 1969; Colloquium on the Geochronology of Phanerozoic Orogenic Belts, 1969).

Basic research on U-Pb systems in sphene from acidic to basic rocks has demonstrated the suitability of this mineral in determining both the primary age and the time of metamorphism (G. R. Tilton and M. Grünenfelder, 1968 and 1969).

Literature

Colloquium on the Geochronology of Phanerozoic Orogenic Belts, Field Trip, Switzerland 1969.

B. Grauert (1969): Die Entwicklungsgeschichte des Silvretta-Kristallins auf Grund radiometrischer Altersbestimmungen. München, Steinbauer & Rau.

B. Grauert und A. Arnold (1968): Deutung diskordanter Zirkonalter der Silvrettadecke und des Gotthardmassivs (Schweizer Alpen). Contr. Mineral. Petrol. *20*.

G. N. Hanson, M. Grünenfelder and G. Soptrayanova (1969): The geochronology of a recrystallized tectonite in Switzerland – the Roffine gneiss. Earth and Planetary Sci. Letters *5*.

F. McDowell (1968): Potassium-Argon Ages from the Ceneri Zone of Southern Switzerland. SMPM *48*/1.

F. McDowell and R. Schmid (1968): Potassium-Argon Ages from the Valle d'Ossola Section of Ivrea-Verbano Zone (Northern Italy). SMPM *48*/1.

R. T. Pidgeon, V. Köppel and M. Grünenfelder (1963): Isotopic U-Pb-Ages of Zircons from the Ceneri Zone of Southern Switzerland. SMPM *48*/1.

R. T. Pidgeon, V. Köppel and M. Grünenfelder (1970): U-Pb Isotope Relationship in Zircon suites from a Para- and ortho-gneiss from the Ceneri Zone, Southern Switzerland. Contr. Mineral. Petrol. *26*.

P. Signer and F. McDowell (1970): On-Line Ar Extraction System for Rapid High-Precision Routine Analysis. Eclogae geol. Helv. *63*/1.

G. R. Tilton and M. Grünenfelder (1968): Sphene: Uranium-Lead Ages. Science *159*.

— (1969): U-Pb-Zerfallsalter von Titanit. Beitr. Geol. Jb. *80*.

Prof. E. Jäger and **co-workers** (Mineralogisch-petrographisches Institut der Universität Bern, Bern).

Isotopic studies (incl. age determinations)

By detailed Rb-Sr and K-Ar age determinations, we were able to study the meaning of age results and, additionally, to obtain information on the cooling history of the Alps after the last phase of metamorphism. Work has been concentrated on samples from the central Swiss and Italian Alps. In this area Rb-Sr age results on micas agree well with the grade of Alpine metamorphism, biotites and muscovites from rocks of low grade metamorphism giving pre-Alpine age results of about 300 m.y. In the zone of the highest degree of Alpine metamorphism, only young Tertiary mica ages were found. These young age results are not randomly spread over the whole area but they change gradually with geographic position.

The young Rb-Sr ages on micas – from 11 to 30 m.y. – indicate the time of cooling to a certain temperature after the last phase of Alpine metamorphism. Muscovite, as compared to biotite, begins to form a closed system earlier in the cooling history, that is, at higher temperatures. Therefore muscovites generally give higher Rb-Sr age results than biotites, the difference being constant – about 8 m.y. – for several rocks of different regions and of different ages. For these rocks the rate of cooling must have been the same. A smaller age difference of 1.7 m.y. was found only for the Verampio gneiss. This rock belongs to the deepest tectonic unit and it occurs in a small window in the center of a dome. This indicates that the center of the dome began to cool later, but after this, it was uplifted and cooled quicker than the neighbouring rocks of higher tectonic units. The doming must have occurred during the cooling time after the last phase of Alpine metamorphism and was completed when biotites became closed systems.

During the cooling period muscovites become closed systems at higher temperatures than biotites, but they can form at lower temperatures. Therefore, in other areas of lower grade of metamorphism, Rb-Sr ages on muscovites and phengites date the time of formation and not a cooling time. In the different areas the formation of these micas has been dated at 35–38 m.y., which corresponds well with the time of the younger phase of Alpine metamorphism.

The region with the youngest Rb-Sr ages on biotites, about 11 m.y., does not exactly correspond with the region of the highest degree of Alpine metamorphism; this means that regions of highest temperatures were cooled earlier (Ticino area) than regions which did not reach these high temperatures (Simplon area). This corresponds well with the data of recent heat-flow; the highest heat-flow is found in the area of the youngest Rb-Sr age results on biotites.

K-Ar and Rb-Sr age determinations on biotites give similar results; both methods determine the time of cooling to a certain temperature. Under conditions of regional metamorphism the K-Ar ages on biotites may be less influenced than the Rb-Sr age data. Our Rb-Sr ages on biotites seem little affected by any erratic base exchange process; as one finds a good regional concordance of the Rb-Sr ages with each other and with the K-Ar ages.

West and East of the Ticino culmination an older, Cretaceous phase of Alpine metamorphism, has be proved.

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B. GRAUERT (1966): Rb-Sr age determinations on orthogneisses of the Silvretta (Switzerland). Earth and Plan. Sci. Letters *1*, 139.

J. C. HUNZIKER (1969): Rb-Sr-Altersbestimmungen aus den Walliser Alpen; Hellglimmer- und Gesamtgesteinsalterswerte. Eclogae geol. Helv. *62*/2.

E. JÄGER (1962): Rb-Sr Age Determinations on Micas and Total rocks from the Alps. J. Geophys. Research, *67*, 5293.

E. JÄGER, E. NIGGLI and E. WENK (1967): Rb-Sr-Altersbestimmungen an Glimmern der Zentralalpen. Beitr. geol. Karte Schweiz, N.F. *134*.

RADIOACTIVITY OF ROCKS

Prof. F. de Quervain (Schweizerische Geotechnische Kommission, Zürich), **Prof. Th. Hügi** (Abteilung für Geochemie des Mineralogisch-petrographischen Instituts der Universität Bern) and **co-workers.**

The research program of the "Committee for the Investigation of radioactive and rare elements in Switzerland" is still in progress. The program includes radiometric surveying (surface and galleries), mineralogical and chemical investigations on radioactive minerals and rocks, and evaluation of radiometric anomalies. The following publications of the series „Untersuchungen über radioaktive Mineralien und Gesteine der Schweiz“ deal with the results of recent investigations:

Literature

F. BIANCONI e A. SIMONETTI (1967): La brannerite e la sua paragenesi nelle pegmatite di Lodrino (Ct. Ticino). SMPM *47*/2.
V. DIETRICH, N. HUONDER and L. RYBACH (1967): Uranvererzungen im Druckstollen Ferrera-Val Niemet. Beitr. Geol. Schweiz, Geotechn. Ser. Lfg. 44.
P. FÖHN und L. RYBACH (1967): Das Radioaktivitätsprofil Fuorcla da Punteglias-Alp da Punteglias (Graubünden). SMPM *47*/2.
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REGIONAL METAMORPHISM

(see also reports on ophiolite investigations)

Dr. M. Frey and **Prof. E. Niggli** (Mineralogisch-petrographisches Institut der Universität Bern, Bern).

Investigations on the Metamorphism of Mesozoic Sediments of Switzerland

The incentive for the investigations was the idea to trace progressive Alpine metamorphism of a formation with approximately the same primary, sedimentary facies. Such a formation is the Keuper which can be followed from the Jura mountains (the unmetamorphosed region) to the boreholes in the Molasse basin, to the Helvetic zone and thence to the Lepontine region (area with highest Alpine metamorphic grade; amphibolite facies). In addition, the Keuper, with its clays, marls and sandstones was selected because the Hercynian (Variscian) orogeny had ceased completely at that time, while Alpine orogenic effects were absent. These investigations showed (FREY, 1968, 1969a) that a distinct metamorphic influence is already detectable in the clayey and marly sediments of the Helvetic nappes of the Glarus alps. The investigations on weak Alpine metamorphism were then extended to other post-Triassic rocks; for example, to the clayey and marly rocks of the lower Liassic (FREY, 1970). In the following some important results are summarized.

In the anchizone Al-rich chlorite and muscovite (partly phengitic) are formed of a mixed-layer illite-montmorillonite of the unmetamorphosed clays; pyrophyllite forms from kaolinite. For the newly formed paragonite, the following sequence is proposed: irregular mixed-layer illite-montmorillonite → regular mixed-layer mica-montmorillonite → mixed-layer paragonite-muscovite → paragonite. Besides the formation of new minerals in the transition zone (anchizone) between diagenesis and greenschist facies, other changes with increasing metamorphic grade are: the crystallinity of illite increases; 1 Md illite changes to 2 M_1 muscovite; the slates change colour from red to pink due to the increasing solid solution of TiO_2 in hematite; the mean density increases; and textural changes occur due to reactions between clastic quartz and clay cement.

In the greenschist facies (Urseren zone and most northern parts of the southern sediment cover of the Gotthard massif) the following minerals are newly formed in pelitic and marly rocks: chloritoid (triclinic and Mg-poor in the lower greenschist facies, monoclinic and Mg-richer in the higher greenschist facies and staurolite zone); margarite (especially in the Liassic), biotite, albite to oligoclase, garnet, kyanite (in the highest greenschist facies), epidote and rarely actinolite.

In the southern adjacent zone of the lower amphibolite facies chloritoid is replaced by staurolite, kyanite becomes more abundant, plagioclase becomes more calcic in chemically-suited host rocks, hornblende (Al-rich) is formed by reaction of pelitic material with dolomite (at the same time the CO_2 content of the rocks strongly decreases) and garnet is abundant.

Tourmaline is zoned with a darker clastic center and a newly-grown, lighter-coloured rim. In the higher greenschist and lower amphibolite facies the ratio of these two portions can be used as a metamorphic indicator, the proportion of rim increasing with grade.

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Prof. E. Nickel, Prof. J. von Raumer and **co-workers** (Institut de Minéralogie et de Petrographie de l'Université de Fribourg, Fribourg).

a) Metamorphic and magmatic history of Hercynian complexes Odenwald

The direction of the southern Rhine-Valley, a rift valley of Tertiary age, has been influenced by older lineations of Hercynian age. Investigations show relationships between formation of first lineations and magmatic events (Nickel, 1952, 1954, 1955, 1965 and Nickel and Obelode-Dönhoff, 1968).

The crystalline basement is composed of Precambrian and Paleozoic series with mineral-assemblages of cordierite-amphibolite (Abukuma-Type) – and pyroxene-hornfels-facies – grade (von Raumer, 1971), due to syntectonic intrusions of gabbroic to dioritic composition (M. Maggetti, 1970, 1971 a, 1971 b).

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b) Alpine complexes: Crystalline basement and Alpine metamorphism in Mt.-Blanc region

The geological history of the Mt.-Blanc-Massif is of a composite nature due to superposition of at least 3 metamorphic cycles (Caledonian, Hercynian, Alpine). During Alpine metamorphism the Hercynian basement, showing polymetamorphic assemblages of higher amphibolite-facies grade, underwent mineral transformations characteristic of lowest (prehnite, pumpellyite, laumontite) and greenschist-facies grade (biotite, stilpnomelane, chlorite, albite, epidote).

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Prof. E. Niggli and **co-workers** (Mineralogisch-petrographisches Institut der Universität Bern, Bern).

The zones of the young, Alpine metamorphism in the *Central Alps* show a relatively simple pattern in contrast to the complex Alpine tectonic structures.

The zone of highest degree of metamorphism occurs in the Simplon and Ticino regions (deepest tectonic units of the Alps; axial culmination!) with an outlier to the east towards the Tertiary Bergell granite. The character of the metamorphism, however, changes towards the Bergell region. Kyanite, which is very common in the rocks of the Simplon-Ticino region disappears while andalusite, cordierite, and wollastonite appear. This represents a change from a regional metamorphic series of the Barrow type to a normal contact metamorphic series. The regional metamorphism in the Simplon-Ticino region is interpreted as a load metamorphism caused by tectonic burial during the formation of the Alpine nappes. At this time, rock thicknesses of 15–30 kilometers must have covered this region.

Outside the zone of almandine amphibolite facies, Alpine glaucophane occurs as an early metamorphic mineral in two regions in the Central Alps: in the canton of Graubünden in the east and in the canton of Wallis in the west. This indicates the existence of high pressures and low temperatures during an early phase of Alpine metamorphism. This is easily explained by the previously mentioned hypothesis of load metamorphism. The pressure increased with load without any significant time lag whereas the temperature rise would have been much slower.

Denudation rates from geochronologic and heat flow data (CLARK and JÄGER) agree with this hypothesis and are reasonable. The application of the method of stress effects around quartz inclusions in garnet (Rosenfeld) indicates high pressures too ($\sim$ 30 km of rock load in the northern Ticino region). The rather large volume of material subsequently removed can be easily accounted for in Molasse deposits (in the north of the Alps) and the deposits of the Po-plain region in the south.

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Dr. R. Schmid (Institut für Kristallographie und Petrographie der Eidgenössischen Technischen Hochschule, Zürich).

Metamorphism of the Ivrea-Zone

Mineralogical-petrological work in a 40 km² part of the Ivrea-Zone shows a continuous increase of metamorphic grade perpendicular to the longest extent of the zone, from the upper amphibolite to the granulite facies. New, unpublished investigations show also a continuous degranitisation (up to 70 vol.-%) in direction of this progressive metamorphism. Both effects are probably caused by the intrusion of basic and ultrabasic magmas in metamorphosed pelitic schists. Several isograds, characterizing this progressive metamorphism, can be drawn by means of the chemical composition of garnet or biotite, and by the modal ratio $g = \text{garnet}/(\text{garnet} + \text{biotite})$ in paragneisses containing garnet, biotite, quartz and sillimanite $\pm$ potassium feldspar, plagioclase, graphite.

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Prof. A. Steck (Institut de Minéralogie de l'Université, Lausanne).

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Prof. E. Wenk and **co-workers** (Mineralogisch-petrographisches Institut der Universität Basel, Basel).

Tertiary regional metamorphism and ultrametamorphism in the deep zones of the Central Alps

Continuation of work on isograds and isograde surfaces in migmatites and on distribution coefficients of elements between coexisting mineral phases. Comparative studies on relict igneous and on metamorphic mineral assemblages in ultramafic rocks. Data permit a rough estimate of p-T conditions during metamorphic events. Further work is in progress.

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OPHIOLITES; ECLOGITES

Prof. P. Bearth (Mineralogisch-petrographisches Institut der Universität Basel, Basel).

Investigations on the ophiolites of the Alps

The investigation has been continued. In the 1967-paper the author published a comprehensive work, which dealt principally with the metamorphism and presented a number of analyses of rocks and minerals, including geological observations. Since then the research has been concentrated on a much smaller, but representative group, which includes eclogites, glaucophanitic rocks, amphibolites and prasinites derived from gabbros or volcanic rocks. It is becoming more and more evident that the metamorphic history of these rocks is different from what is known from other regions (California, Japan).

We have continued the study of the Allalin gabbro, partly with the aid of Dr. G. Chinner and Prof. Schwander. The microscopic and electron-microprobe analyses have shown that kyanite plays an important rôle, particularly the breakdown of the anorthite-molecule to zoisite and kyanite (Bearth, 1970). However, there are, in the Allalin gabbro, other reactions involving kyanite. The principal aim of this study is to acquire a better insight into the history of the development of Alpine metamorphism in the inner arc of the Western Alps.

Literature

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Prof. R. Chessex (Département de Minéralogie de l'Université de Genève, Genève).

Contribution to the knowledge of some eclogitic rocks

Some of the main physical and chemical properties of eclogitic rocks were studied. This work is not yet completed and, in fact, we have only a few results to present.

Our study comprises:

1. Field work, in order to decipher the field relations between the eclogites and the enclosing rocks.
2. Petrographical study in the laboratory for the determination of the main physical properties of the eclogites.
3. Chemical study of the eclogites.
4. Physical and chemical study of some eclogite minerals.

The rocks which are currently studied belong to the following areas and units:

A. Crystalline basement from Corsica (Mediterranean realm) mainly composed of eruptive, metamorphic and migmatitic rocks. Varisc-Hercynian age, and older?

B. Aiguilles-Rouges massif, one of the external crystalline massifs of the Alps. The main facies are essentially metamorphic and migmatitic rocks. Variscan-Hercynian and pre-Variscan age.

C. Crystalline basement of the Grand-Saint-Bernard penninic nappe (the so-called "Casanna Schists"), the age of which is debatable but probably in great part Permo-Carboniferous. The rocks are mainly metasedimentary and metavolcanics metamorphosed in the greenschist and blueschist facies.

A. Crystalline basement of Corsica

Tectonic unit: Hercynian or, more probably, pre-Hercynian basement in the south-eastern part of the island.
Location: North of Porto-Vecchio, 2 hundred meters north of the bridge across the Conca river, just north of the Tour Gênoise de la Parata.
Occurrence: The "eclogite" is enclosed in metamorphic and migmatitic rocks; the main facies are: gneiss, amphibolites and different types of migmatites to anatectic granite.
Metamorphism: Amphibolite facies in a migmatitic series.

Characteristics of the "eclogite":

One thin bed (10 to 20 cm thick) in gneissic rocks. Moderately altered and retrogressive. Colour: light grey-green with pink garnet.

Mineralogy: little porphyroblasts of fresh garnet in granoblastic pyroxene strongly altered in clinozoisite-pistacite. Accessories: apatite, ilmenite, titanite.

Chemistry:

	Co 1	A 10
SiO_2	39.43	39.38
TiO_2	1.19	0.41
Al_2O_3	18.15	17.79
Fe_2O_3	4.70	5.68
FeO	7.91	14.25
MnO	0.17	0.38
MgO	2.14	1.24
CaO	18.72	18.70
Na_2O	3.35	1.06
K_2O	1.79	0.43
P_2O_5	0.34	0.24
H_2O^+	1.73	0.24
H_2O^-	0.08	0.02
CO_2	0.14	—
	99.76	99.80

The primary material is probably not a basalt, but rather a sedimentary rock. Notice the low amount of SiO_2 and the high concentration in CaO. (Analysis Co 1.)

Garnet is not of eclogitic composition. The concentration in CaO is too high and MgO too low. (Analysis A 10.)

The pyroxene is not an omphacite but a diopside.

Conclusion: this rock is not an eclogite. It may probably be considered as an old impure carbonate rock (tactite).

Density: 3.14
Analyst: N. Monnier (Geneva)

B. Aiguilles-Rouges massif (external crystalline massif of the Alps.

Tectonic unit: Aiguilles-Rouges Brévent series, which is the core of the massif.
Location: Lake Cornu, above Chamonix.
Occurrence: The "eclogite" is enclosed in metamorphic rocks, partly migmatized. The main faces are: different types of gneiss and migmatites, amphibolites, some marble beds.
Metamorphism: Amphibolite facies.

Characteristics of the "eclogite":

Described in the thesis by JOUKOWSKY. The rock is generally retrogressed to amphibolite. Concordant to sub-concordant with the gneiss foliation.

Interpreted by Oulianoff as of metasedimentary origin (limestone). However, an igneous origin seems more probable.

Mineralogy: garnet, pyroxene, amphibole, plagioclase, symplectite; Retrogression phenomena are evident.

Chemistry:

SiO_2	50.85
TiO_2	1.61
Al_2O_3	13.99
Fe_2O_3	3.42
FeO	10.32
MnO	0.28
MgO	6.94
CaO	7.89
Na_2O	2.82
K_2O	0.10
P_2O_5	0.28
H_2O^+	0.82
H_2O^-	0.24
CO_2	0.60
	99.92

The composition is basaltic. The pyroxene is not an omphacite (less than 1% Na_2O). The garnet has approximately the following composition: 3 almandine + 1 pyrope + 1 grossularite.

Density: 3.14
Analyst: N. Monnier (Geneva)

C. Crystalline basement of the Grand-Saint-Bernard nappe (Pennine Alps)

Tectonic unit: Crystalline core ("Schistes de Casanna") of the middle penninic nappe of the Grand-Saint-Bernard, Western Alps, Valais (Switzerland).
Location: Coupole de Boussine, val de Bagnes, above the Mauvoisin lake.
Occurrence: The "eclogite", in lenses of some meters thick, is enclosed in schists of pelitic to basic composition (sericite-chlorite-epidote, chloritoid-glaucophane schists).
Metamorphism: Greenschist to blueschist facies.

Characteristics of the eclogite:

Fine-grained rock, massiv and very hard.
Mineralogy: garnet, pyroxene, glaucophane, epidote, chlorite.

Chemistry:

SiO_2	45.16
TiO_2	3.23
Al_2O_3	14.53
Fe_2O_3	6.89
FeO	8.67
MnO	0.28
MgO	5.99
CaO	7.14
Na_2O	3.96
K_2O	1.06
P_2O_5	0.34
H_2O^+	2.37
CO_2	0.43
	100.05

The original rock is, as the prasinites, of basic igneous origin.

Niggli parameters:

si = 107
al = 20
fm = 51
c = 18
alk = 11

Prof. A. Gansser and **co-workers** (Geologisches Institut der Eidgenössischen Technischen Hochschule und der Universität Zürich, Zürich).

Ophiolite investigations

The work on the Ophiolites of the Piz Platta region (Central Grisons) has been completed by V. DIETRICH. An interesting stratigraphy from intrusives through diabases to pillow lavas has been established, as well as an age relationship with adacent Upper Cretaceous calc-schists.

The ultrabasic rocks of the Chiavenna region have been followed into the Tertiary Bergell massif, where an interesting suite of ultrabasic xenolithes is present.

The work on one of the largest ophiolite complexes of the Alps, in the Malenco region, is continuing. In connection with the International Commission on Structural Geology a comparison of the ophiolites of central Switzerland and the northern Apennines was made. It is most likely that these ophiolitic belts reflect mantle areas with little sialic crust.

The following publications regarding these activities were made:

Literature

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— (1970): Die Stratigraphie der Platta-Decke. Fazielle Zusammenhänge zwischen Oberpenninikum und Unterostalpin. Eclogae geol. Helv. *63*/2.

D. FERRINI (1964): Le pietre verdi dei dintorni di Chiavenna. Diploma work Geological Institute ETH Zürich, unpublished.

R. GERBER (1966): Geologie des Malenco-Serpentins östlich des Passo d'Ur. Diploma work Geological Institute ETH Zürich, unpublished.

H.-U. SCHMUTZ (1968): Geologisch-petrographische Untersuchungen östlich Chiavenna (Italien). Diploma work Geological Institute ETH Zürich, unpublished.

Prof. Tj. Peters (Mineralogisch-petrographisches Institut der Universität Bern, Bern).

Alpinotype peridotites and associated rocks in the Alps

The spinel-bearing pyroxenitic layers of the serpentinized lherzolite of the Totalp were compared with those within the lherzolites of Lherz (Pyrenees). The Totalp pyroxenites, which often contain highly pyrope enriched garnets ($Py_{76}Alm_{13}Gr_6$ And_4Uw_1), are only slightly serpentinized and are practically identical with the fresh pyroxenites of the Pyrenees. The Totalp lherzolite lies in a region which is almost unaffected by Alpine metamorphism. Rocks similar to these pyroxenites were found with the serpentinites of Oberhalbstein and these are now being investigated.

The distribution coefficients of Mg and Fe in coexisting orthopyroxenes, clinopyroxenes and olivines of the Totalp lherzolite indicates an equilibrium temperature of around 1400° C. The Ca/Ca+Mg ratios in the clinopyroxenes indicate temperatures between 800° and 1000° C. This discrepancy in temperature estimations can partly be explained by the high Al_2O_3-contents of the clinopyroxenes, since a good correlation between Al_2O_3-contents and Ca/Ca+Mg ratio was found. The Na_2O-content of the clinopyroxenes decreases in the successive pyroxenites that differentiated from the main lherzolite. From the mineralogical composition of the different rock types and the chemical compositions of the minerals it is concluded that the Totalp peridotite originated in the Upper Mantle.

In the Malenco serpentinite, the clinopyroxenes formed during the rather strong Alpine metamorphism are much poorer in Al_2O_3 and Na_2O than the primary clinopyroxenes. On the other hand, the olivines, grown postdeformationally during the Alpine metamorphism, are not much different in composition from the primary olivines.

Literature

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TJ. PETERS and E. NIGGLI (1964): Spinellführende Pyroxenite (Ariégite) in den Lherzolitkörpern von Lherz und Umgebung (Ariège, Pyrenäen) und der Totalp (Graubünden), ein Vergleich. SMPM *44*, 61–81.

Prof. M. Vuagnat and **co-workers** (Institut de Minéralogie de l'Université de Genève, Genève).

Research on ophiolites and related rocks

1. Petrological, mineralogical and geochemical investigations on ophiolites of the Western Alps:

   a) Montgenèvre Massif (France and Italy).
   b) Ophiolites of the Haute-Ubaye (France).
   c) Ophiolites of the Versoyen (France and Italy).
   d) Ophiolites of the Col des Gets region (France).

   Main results: existence of a separate tectonic unit made up of ophiolites and a characteristic, rather thin sedimentary cover; progressive metamorphism of the ophiolites from the prehnite-pumpellyite facies to either the greenschist facies or the blue schist facies; establishment of the ophispherites as a special class of rodingites.

2. Petrological, mineralogical and geochemical investigations on ophiolites of Turkey.

   Main results: existence of an extensive zone of ophiolites in the blue schist facies (with most of the typical mineral associations of the Franciscan rocks in California) in the region of Mihaliçik (Eskisehir Vilayet); interpretation of the Kizil Dag ophiolitic Massif (Hatay) as a piece of oceanic crust and upper mantle.

3. Petrological, mineralogical and geochemical investigations of some ophiolites of the Caribbean area: Cuba, Porto Rico, Virgin Islands, Guatemala.

   Main restults: emplacement as cold intrusion under tectonic control of all the investigated serpentinite masses of Cuba; existence of a great number of rodingites and tectonic inclusions in the serpentinites of Cuba, Porto Rico and Guatemala.

4. Petrological, mineralogical and geochemical investigation of volcanic graywackes of Tertiary age in the Western Alps and in the Apennines.

   Main results: existence of an extensive zone of rocks in the zeolite facies (with several subfacies: laumontite-prehnite, pumpellyite-prehnite, etc.) in tectonic units of the Alps and Apennines which were previously considered unmetamorphosed; formation of albite-chlorite assemblages in volcanic rocks (spilitic „facies") as a result of low-grade metamorphism.

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*) SPHN = Société de Physique et d'Histoire naturelle.

RHINEGRABEN

Prof. H. Laubscher (Geologisches Institut der Universität Basel, Basel).

As a contribution to the analysis of world rift systems generally, and the Rhinegraben in particular, H. Laubscher has been working on essential aspects of the southern end of the Rhinegraben around Basel and under the Jura mountains. This was done partly as a Swiss contribution to the international (mostly German-French) "Project Rhinegraben". His analysis lead to the view that the southern end of the graben is characterized by a mainly sinistral transform fault zone, along which a large part of the EW extension is transferred from the Rhinegraben to the Bressegraben. He also organized an excursion of the Swiss Geological Society in the southeastern end of the Rhinegraben. Results are contained in the following publications.

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ZONE IVREA-VERBANO SENSU LATISSIMO

Report on the "Symposium Ivrea-Verbano zone"

This International Congress originated within the Swiss Upper Mantle Committee. It was organized by Prof. Dr. E. Niggli, Bern (President of the Symposium) and Dr. R. Schmid, Zürich (Secretary) with collaboration of Italian and German colleagues and was supported by private economic institutions of Switzerland as well as state institutions of Italy and Switzerland.

The Symposium consisted of two parts, a Congress at Locarno, Switzerland, from 30th March to 1st April, and a geological excursion from 1st to 3rd April 1968. 105 earth scientits of six European countries (Belgium, France, Western Germany, Italy, The Netherlands, and Switzerland) were present at the Congress, and 69 of them took part in the excursion.

At the Congress the latest results on the geophysics, petrology, and geochronology of the Ivrea-Verbano zone and the adjoing areas were presented. They were published in 1968 in the „Schweizerische Mineralogische und Petrographische Mitteilungen" Vol. 48/1 as scientific report Nr. 20 of the Upper Mantle Project*).

The Ivrea-Verbano zone is a 110 km long and 10 km broad rock unit consisting of metamorphic mafic, ultramafic and pelitic rocks in granulite and amphibolite facies. It crops out in the Southern Alps at the boundary with the Central Alps, and is separated from them by a fault line. The seismic and gravimetric results indicate

*) This volume may be ordered from Verlag Leemann, Postfach, 8034 Zürich, Switzerland.

that the Ivrea-Verbano zone is the uppermost part of a vast body, dipping SE down to the upper mantle, and representing a large slice from the transition zone between crust and mantle thrust up in pre-alpine time. For this reason German, Italian and Swiss participants in the Congress decided to carry out heat flow measurements in the Ivrea-Verbano zone. This plan was realized in 1970/71, and the results of these measurements will soon be published.

OTHER SUBJECTS

Dr. K. Bächtiger (Institut für Kristallographie und Petrographie der Eidgenössischen Technischen Hochschule, Zürich).

On the origin of native gold, quartz crystals and thermal water in the surroundings of Calanda mountain (Kt. Graubünden and Kt. St. Gallen)

Detaled field investigations were undertaken by the author in recent years (1966, 1967, 1968, 1969a, b, 1972) on the pyrite-arsenopyrite impregnations in lower Dogger shales and on native gold (+ pyrite) in calcite/quartz (+ dolomite, siderite) veins in the same material in the old gold mine called "Goldene Sonne" (SELB, 1812). These mineralizations not only occur in steeply dipping filled fissures, as it was thought till now, but also as impregnations of the wall-rock along Alpine thrust planes, sometimes forming larger quartz-calcite layered masses as saddle deposits etc. On the other hand since these mineralizations and the thrust planes may be derived from the Helvetic "root zone" a few 100 m SE of the gold-arsenic deposition, it seems clear that these mineralizations with Alpine fissure minerals must be a product of late Alpine folding and thrust dislocations (CADISCH, 1939). The *whole mineralization is therefore very similar to many gold veins of the so-called Monte Rosa gold-district* (HUTTENLOCHER, 1934; STELLA, 1943) NW of the Ivrea-Zone, which is considered to consist partly of upper mantle material (E. NIGGLI, 1946). As it is thought that the thrust planes and the "root zones" extent to great depths in the earth crust, perhaps as far as to the upper mantle, the gold solutions too may be derived from these great depths using the mentioned tectonic features for upward movement.

Inclusions of pyrite and very fine octahedral crystals of native gold in a few quartz crystals from Calanda Mt. indicate a *close genetic correlation* between the gold/sulphide deposition and the phase of Alpine fissure mineralization. This may also be the reason why *quartz crystals* especially from the immediate neighbourhood of the main gold vein show the *highest effects of natural thermoluminescence (TL)* so far obtained in Switzerland. Quartz crystals from more distant fissures in Triassic dolomite have minor TL effects; those from most remote fissures in a Permian eruptive rock series show no natural effects. But according to measurements of neutron activation by Dr. L. Rybach (personal communication) the latter crystals contain traces of antimony. Also the *composition of gas-liquid-inclusions in quartz crystals* from a nearby quartz-lead vein of Alpine age led Prof. Dr. Deicha (personal communication) to the conclusion that even these substances must have been transported *from more internal parts of the earth.* All these properties indicate the special character, genesis and origin of this gold-quartz-calcite mineralization as opposed to other similar occurrences in Switzerland.

Recent measurements at the neighbouring hot spring of Pfäfers/Bad Ragaz by E. WEBER (1969) revealed that the *chemistra and temperature* is practically *constant* throughout the whole year (36,5°C), whilst the volume of outflow, besides climatic variations, shows *tidal oscillations* that are probably connected with the elevation of the earth's crust by the moon.

This hot spring may therefore be considered as the last manifestation of the mineralizing solutions that probably, at the end of Tertiary (and from the interior of the earth) introduced first the ore minerals pyrite (in part), and arsenopyrite, and afterwards, the Alpine fissure minerals quartz, talc, pyrite, calcite, dolomite, native gold, and fluorite.

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Prof. F. Laves, Dr. M. Corlett, Dr. E. Eberhard, R. Gubser, Dr. L. Rybach, Dr. K. Viswanathan, Dr. H. U. Nissen (Institut für Kristallographie und Petrographie der Eidgenössischen Technischen Hochschule, Zürich); in part in collaboration with Prof. P. Ribbe, University of Virginia.

Feldspar studies (with respect to structural state and "impurities")

In 120 *adularia* crystals, collected from fissures in the Central Alps where they were formed during the late stages of deformation and cooling of the Alps, the *sodium* contents have been determined by a neutron activation procedure (Rybach and Nissen, 1967). The regional distribution of the sodium (albite) contents shows a maximum (up to 12 mole-% Ab) in and around the Gotthard and Simplon areas (Nissen and Rybach, 1971). It has been suggested (Nissen, 1967) that the sodium content reflects temperature differences within the Alps during growth of the adularias.

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Prof. E. Nickel and **co-workers** (Mineralogisch-Petrographisches Institut der Universität Fribourg, Schweiz).

Structural behaviour of liquids of high viscosity in hydraulic apparatus

The aim of this work is to reproduce the structures of moving and consolidating granites by the use of viscous liquids with incorporated particles (e. g. glucose with grains of rice). Completely homogeneous viscous liquids must be used to obtain structures described by CLOOS as domes. Inhomogeneities produce a "channeling" of streaming material and small domes with flow-structures result. Using two phase systems (liquids of different viscosity) it is possible to vary the laboratory parameters to produce structures similar to those found in nature.

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Dr. H.-U. Nissen (Labor für Elektronenmikroskopie II, ETH-Aussenstation Hönggerberg, Zürich).

Exsolution in plagioclases of deep seated anorthosites, amphibolites, etc.

Re-investigation of calcic plagioclases in high grade metamorphic rocks such as gabbroic amphibolites, norites, anorthosites and other basic rocks from Scotland, Norway, USA, Africa, etc., has led to the discovery of lammellar exsolution textures in these plagioclases. The work is being continued and the results will be available shortly of a habilitation thesis at the ETH. The rocks investigated include those from the Ivrea Zone which has been assumed to contain Upper Mantle material modified by later events. The work is carried out with X-ray, electron-diffraction, electron microscopic and optical methods. The results may be pertinent to the subsolidus relations of plagioclases, to the estimate of the temperature of formation of these rocks.

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