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Alpine geology: whence, whither?

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It is a pleasant task for an old geologist to look back at the development of his branch of our science, to wonder from where we have come, where we are standing and where we might be going. To be sure, we should start with Horace-Bénédict de Saussure, going on the painstaking work of unravelling Alpine stratigraphy, to Albert Heim and the deformation of rocks and finally to the discovery of nappes; but I shall limit myself to the century which is coming to its close. I am confident that nobody will expect a dispassionate treatment of the matter.

The first half-century

With the advent of nappe tectonics – hesitatingly foreseen by Arnold Escher (Murchison 1849), discovered by Marcel Bertrand (1884), demonstrated by Hans Schardt (1893), propagated by Maurice Lugeon (1902) and Pierre Termier (1904) – the most exciting chapter of Alpine geology began. The apparent chaos of structures and facies zones fell into order. The Alps themselves were now considered as a sort of model: nappes were discovered everywhere, most of them real, some of them imaginary.

The fortunate geologists of the first twenty years of the century do not seem to have worried about the global implications of their results; exploring the mountains was much more fun. In spite of this, the discovery of nappe structures, almost simultaneously in the Alps, in the Scottish Highlands (Lapworth 1883) and in the Scandinavian Caledonides (Törnebohm 1888), had a considerable theoretical impact. The crustal shortening observed was no more compatible with the theory of contraction by cooling as motor for the folding of mountain chains. Together with the recognition of radioactive heat generation, it served to discredit a model which had held sway for several decades, but without substituting another one in its place.

The new model had to wait for Alfred Wegener, who formulated the Continental Drift hypothesis, and for Emile Argand, along with Eduard Suess the only genius among alpine geologists. Argand (1911) introduced the method of constructing profiles by oblique projection along fold axes, and he proposed (1920) the embryotectonics hypothesis, according to which nappes arose from pre-existing (essentially Mesozoic) asymmetric folds. Together with Wegenerian mobilism, these two postulates provided a genetical link between geometrical structures and paleogeographic development, thus constituting the theoretical base for the «cylindristic» attempts at along-strike nappe correlation of the twenties.

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The Wegener-Argand synthesis provided a satisfactory model for the time being. Still, only few geologists (e.g. Léon W. Collet 1927 and Rudolf Staub 1924) tried to apply it in a constructive manner. Leopold Kober's (1923) system was less resolutely mobilistic.

Sometime around 1934, the classical period of alpine geology ran out of breath. In the excellent field guide, published in that year by the Swiss Geological Society, Argand himself made reservations as to the general validity of the embryotectonics concept. Wegener's drift hypothesis came under attack; the thin floes of continental crust were not strong enough to travel over large distances. Unfortunately, the child was spilled with the bath, and the sound evidence for mobile continents, furnished by the crustal shortening in the Alpine chains and by the striking similarity between the southern continents, was overruled. It is significant that only one South African scientist (Alexis du Toit) and a few Alpine geologists still openly adhered to the drift theory.

On the whole, the last years of the half-century were not a particularly exciting time in alpine geology. Much good field work was done and excellent geological maps were produced. An important new tool, micropaleontology, was introduced. In some countries, the sharp separation between geology and petrology institutes had negative effects. There were few innovative ideas; in 1942, in a seminar talk with the modest title "the origin of mountain belts", I complained about the absence of a comprehensive theory. It came only a quarter of a century later, with plate tectonics.

Otto Ampferer's (1923–31) views on "Verschluckung", prefiguring subduction, met little acceptance, perhaps because they were illustrated by dubious examples. The term "subduction" was proposed, somewhat later, by another Alpine geologist, André Amstutz (1955); this as well was hardly noticed.

On the other hand, nappe formation by gravity gliding, first advocated in the Alps by Daniel Schneegans (1938), enjoyed a brief spell of popularity. It was in concordance with the prevailing neo-fixist, anti-Wegener backlash. The fixist reaction continued into the fifties, especially in the Eastern Alps, with the perverse notion of "Gebundene Tektonik". Even Staub, in some of his late works, sacrified to the current fashion.

The fad of gravity tectonics is a striking example of a supposedly "modern" model (celebrated as such e.g. still in Rutten's 1969 book), which was in the long run counterproductive. It did not stimulate any significant progress of our understanding of the Alps.

The third quarter

Around 1950, Alpine geology received a new impetus, not so much by the emergence of any new model, but simply by the enthusiasm of a new generation of field and laboratory workers. Another important factor was the opening of the frontiers, leading to active cooperation, at first among French, Italian and Swiss geologists.

There were two centers of interest. One concerned the geology of the deeper parts of the chain and the relations between structure and metamorphism. Two Basel geologists, Peter Bearth and Eduard Wenk, deserve a special mention among these explorers. Geochronological data began to appear, by the pioneer work of the Berne laboratory. Alpine metamorphism, at least its most obvious, Tertiary (misnamed Lepontine) stage, came to be partly understood (Niggli 1970). By and by, the polyphase nature of Alpine events was recognized.

The other central theme was Alpine paleogeography and paleotectonics. Mesozoic faults, first signalled by Hans Günzler-Seiffert back in 1942, were now discovered in most Alpine zones; they implied the existence of a tensional régime up to the Late Cretaceous or Paleogene compression, and were of course at variance with the embryotectonics theory. Geologists began to question the nature of the Alpine "geosynclines" and to talk about oceans and continental margins, well before the breakthrough of plate tectonics.

Looking back at the fifties and early sixties, I have the feeling of a productive period; this may be due to personal bias, since I was then able to contribute actively to the reappraisal of Alpine geology. All these new observations were made without a ready-made theory at hand; nevertheless, they resulted in a justification of the mobilistic approach. My 1960 paper (Trümpy 1960) conveys a fair idea of Alpine geology before plate tectonics.

In principle, the alpine geologists should have been prepared to embrace the plate tectonics theory immediately, in the mid-sixties. Apart from Hanspeter Laubscher and a few others, most of them hesitated until the proofs became overwhelming, notably through the predictions verified by the Ocean Drilling Programme. At last, a coherent model became available. It corroborated Argandian mobilism, it brought an outside control of Alpine displacements and it provided a rational explanation of pre-orogenic and orogenic evolution.

The original concept was mainly based on the mid-ocean ridges and on the circum-Pacific chains: I have compared it to Aphrodite, who was very beautiful and who was born out of the sea. The Alpine and Gondwanian evidence for plate movements had only a marginal influence on its elaboration. It soon appeared that the Mediterranean chains, with their small oceans and intricate contours of the affronting plates, offered a special case. Between attempts to adapt the model to the Alps and attempts to adapt the Alps to the model, a very productive discussion arose, which continues up to this time. Plate tectonics, not only in the Alps, proved to be a more complex process than previously imagined; but the impetus provided is still active – perhaps with less enthusiasm than during the two decades after the discovery, as new problems, particularly those connected with the evolution of the Earth's oceans and atmosphere, make the headlines of our science.

One special aspect of the plate tectonics theory was the interpretation of ophiolites as remnants of oceanic crust, foreseen by Gustav Steinmann (1905). Based on a few outcrop areas and on the analysis of ocean seismics, a theoretical model for a complete ophiolite sequence was proposed. This triggered intensive research in the Alps and in similar mountain chains. The result of this campaign was a partial modification of the classical ophiolite model – as all good models should be, it was liable to falsification – and led to a more sophisticated and quite possibly more realistic comprehension of Alpine ophiolites, involving i.a. the tectonic denudation of mantle rocks. But this pertains already to the next period.

Subrecent and recent times

The papers and posters presented at this workshop as well as the summary of the closing round-table discussion cover a fair part of the current preoccupations of Alpine tectonicians; we may therefore be very brief.

In the classical period of alpine tectonics, S to N (in the Western Alps, E to W) thrusting, with subordinate backthrusting, was considered to be the almost exclusive way of nappe transport. Since then, it has been realized that lateral displacement was also of great importance. Large-scale strike-slip faults, of Jurassic to Miocene age, have increasingly been recognized. Triassic lateral displacements are very probably also present in the Dolomites, according to Carlo Doglioni (1984); the frequently postulated but rarely proved Permian shifts belong to the Variscan part of the story. Anomalous thrust directions along the axis of the chain (mainly E to W) also play a much greater role then previously suspected. Flat-lying normal faults (or *lags*, to use the convenient and short word introduced by Sir Edward Bailey [1934, 1936]), were hardly recognized up to a relatively short time ago. The determination of lags and of along-chain displacements is partly due to the analysis of small-scale structures. In many cases, e.g. for the Simplon and the Brenner accidents, the results are highly plausible; in others, there is a discrepancy with the arrangement of large-scale rock masses and facies belts. Apparent contradictions should always be an incentive for further research.

Others will comment on the progress made in understanding Alpine metamorphism and on the results of more numerous and more reliable age data. At the two ends of the time scale, basement geology and Quaternary geology show considerable advances. One of the great adventures was the shooting of reflection seismic profiles through the Alps. They have furnished remarkable results; not all geologists have escaped the temptation to over-interpret them.

A rejoicing observation is the greatly improved cooperation between structural geologists, petrologists and even geophysicists. But gaps between scientific subdisciplines are somewhat like Alpine oceans; when one of them closes (the Meliata ocean resp. the geology / petrology gap), another one opens (the Piemont ocean resp. the hard rock / soft rock gap). It is regrettable that so few Alpine sedimentary geologists attended this meeting. Another disturbing feature is the decline of Alpine paleontology, at least in some countries. Paleobiogeography is an essential tool for plate and terrane reconstructions; kinematic analysis depends on sound and precise biostratigraphical data.

Models are omnipresent in our discussions. They can be highly useful for guiding our thought, and they are indispensable for getting papers accepted in mainstream journals. In the historical part of this talk, I have mentioned some very productive models (e.g. the Wegener-Argand synthesis, or the plate tectonics model), along with at least one misleading and sterile model (gravity tectonics). Both kinds may be around today. Models should not so much be used to be applied but rather to be questioned. In my student days, one of our major scientific joys was to show that the Old Man was wrong. Nowadays, when professors are less awe-inspiring and have lost their aura of infallibility (in continental Europe, A.D. 1968), I hope that young geologists derive the same pleasure from demolishing a model.

What lies ahead?

Past experience renders one extremely wary to predict the possible future development.

The Alps will certainly remain a focus of interest and a most worthwhile object for field and laboratory studies. They should not serve as a model, as they did in the first quarter of this century – this dubious honour has now been taken over by the Canadian Rockies and similar chains – but as a special and particularly intricate case. The heritage of data and ideas is perhaps richer than in any other mountain belt. The Alps will continue to serve as a testing ground for new methods and theories. Geological theories must keep their feet on the ground, i.e. on solid regional geology, which is by no means and never will be obsolete. No synthesis is complete if it disregards field relationships.

On the side of structural geology, I foresee a renewed interest in brittle deformation. Folds are beautiful and amenable to quantitative treatment; fault rocks are ugly, difficult but just as important. The coming generation will have to pay billions of swiss francs for the kakirites underneath the upper Rhine valley.

Another subject of prime interest should be the history of the Alps during the last ten or twenty millions of years. Methods of dating the exposure of Alpine rocks have come of age and have already given impressive, often baffling results. The origin of the Alpine valleys is a challenging problem, with great theoretical and practical implications.

All this needs a consciously multidisciplinary approach, including the breakdown of the institutional barriers between geology and physical geomorphology. The Alps cannot be understood by petrologists, structural geologists, sedimentologists, morphologists or even geophysicists alone. It is also imperative that a close connection be maintained, or renewed, between the "pure" and the practical geologists working in the chain, to their mutual benefit.

What is the future of alpine geology? As usually, William Shakespeare (2^{d} part Henry IV, 4 / 1) has the last word:

You are too shallow, Hastings, much too shallow
To sound the bottom of the after-times.

To those continental geologists who are not familiar with all of Shakespeare's dramas, I should explain that these words were pronounced by Prince John of Lancaster (later the Duke of Bedford), the unpleasant younger brother of the future Henry V. Shortly afterwards, Lord Hastings was beheaded.

Our science politicians would do a great disservice to the entire Earth Sciences if they followed the example of Prince John.

REFERENCES

AMPFERER O. 1923–31: Beiträge zur Auflösung der Mechanik der Alpen. Jahrb. geol. Bundesanstalt Wien 73 (1923); 76 (1926); 78 (1928); 30 (1930); 31 (1931).

AMSTUTZ A. 1955: Subductions successives dans l'Ossola. C. R. Acad. Sci. Paris 241, 967.

ARGAND E. 1911: Les nappes de recouvrement des Alpes Pennines et leurs prolongements structuraux. Mat. Carte géol. Suisse N.S. 31, 1–26.

– 1920: Plissements précurseurs et Plissements tardifs dans les Chaînes de Montagnes. Actes Soc. Helv. Sci. Nat. 101^{me} session, Pt. 2, 13–39.

BAILEY E.B. 1934: West Highland Tectonics: Loch Leven to Glen Roy, Quart. Journ. Geol. Soc. London 79, 125.

– 1936: The Ballachulish Lag at Callert, Loch Leven. Geol. Magazine, 412.

BERTRAND M. 1884: Rapports de structure des Alpes de Glaris et du Bassin Houiller du Nord. Bull. Soc. géol. France (3) 12, 318–330.

COLLET L.W. 1927: The structure of the Alps. Arnold (London).

DOGLIONI C. 1984: Tettonica transpressiva nelle Dolomiti. G. geol. (Bologna) Ser. 3, 46/2, 47–60.

Guide géologique de la Suisse 1934 (Ed. by CHRIST, H. & GAGNEBIN, E.). Fasc. 14 Wepf (Basel).

GÜNZLER-SEIFFERT H. 1942: Persistente Brüche im Jura der Wildhorn-Decke des Berner Oberlandes. Eclogae geol. Helv. 34 (1941), 164–172.

KOBER L. 1923: Bau und Entstehung der Alpen. Bornträger (Berlin).

LAPWORTH C. 1883: The Secret of the Highlands. Geol. Magazine 10, p. 120, 193, 337.

LUGEON M. 1902: Les grandes nappes de recouvrement des Alpes du Chablais et de la Suisse. Bull. Soc. géol. France (4) 1 (1901), 723–825.

MURCHISON R.I. 1849: On the geological structure of the Alps, Apennines and Carpathians. Quart. Journ. Geol. Soc. London 5, 157–312.

NIGGLI E. 1970: Alpine Metamorphose and alpine Gebirgsbildung. Fortschr. Mineralogie 47, 16–26.

RUTTEN M.G. 1969: The Geology of Western Europe. Elsevier (Amsterdam etc.).

SCHARDT H. 1893: Sur l'origine des Préalpes Romandes. Eclogae geol. Helv. 4, 129–142.

SCHNEEGANS D. 1938: La géologie des nappes de l'Ubaye – Embrunais entre la Durance et l'Ubaye. Mat. Carte géol. France.

STAUB R. 1924: Der Bau der Alpen. Beitr. geol. Karte Schweiz N.F. 83.

STEINMANN G. 1905: Geologische Beobachtungen in den Alpen II: Die Schardt'sche Überfaltungstheorie und die geologische Bedeutung der Tiefseeabsätze und der ophiolithischen Massengesteine. Ber. natf. Ges. Freiburg i. Br. 16, 18–67.

TERMIER P. 1904: Les nappes des Alpes Orientales et la synthèse des Alpes. Bull. Soc. géol. France (4) 3 (1903), 711–766.

TÖRNEBOHM A.E. 1888: Om fjällproblemet. Förhandl. Geol. Förening i. Stockholm (117) 10, 328–336.

TRÜMPY R. 1960: Paleotectonic evolution of the Central and Western Alps. Bull. Geol. Soc. America 71, 843–928.

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