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GL 3020

Upper Palaeozoic and Cenozoic History

Lecture course by Prof J.McManus 1999

1. Post-Hercynian Europe

During the lower Palaeozic the plate motions brought together the Laurentian and Baltic cratonic masses with their marginal accretions of sediments as seen in the Southern Uplands of Scotland and the deposits of the Welsh Basin through to the Lake District. Following the Caledonian orogenic activity a period of relative stability was marked by deposition of the molassic deposits of the Old Red Sandstone facies of the Devonian and the widely developed continental shelf limestones and deltaic deposits of the Carboniferous.

Towards the end of the Upper Palaeozoic a further stage of plate clustering, leading to the formation of the massive continent of Pangaea, was marked by the Hercynian orogeny. The plate convergences took place over a long period of geological time, so that their impacts are felt from late Devonian through until the Permian in different geographical areas.

On the European continent the whole event is referred to as the Hercynian orogeny, (named after the Harz mountains), but the earliest phases are often referred to as Variscan or Armorican (Roman province of Brittany). This episode controlled the development of the structure and granitic intrusions of SW England and S.Wales and the southern fringes of Ireland. It was also responsible for creating the essentially anticlinal strucure of northern and central England, giving rise to the coalfield basins to east and west, similarly north-south oriented folds in the Scottish Midland valley, and doubtless reactivation of many of the major Caledonoid fault systems.

The North Sea Basin was occupied by the Zechstein Sea during the Permian, a sea whose boundaries advanced and retreated several times while uplift and intrusion was occurring to the south. The uplift, which created substantial mountains, continued from the late Carboniferous through into the early Permian. Away from the marine influences in the east and between and among the hills were formed red bed successions over most of Britain, with wadi flush deposits and wind blown dune systems recognised from Arran to Dawlish. These late- and post- Hercynian molassic sediments typify those of much of northern Europe through the late Permian and Triassic. The upstanding Hercynian hill masses remain as positive features in many parts of Europe, with the later rocks often only partly covering them. (Fig. 1)

I want to look at features of the Hercynian and post-Hercynian in France, Germany and the Alpine belt from Switzerland through Austria.

In his summary of the Geology of France Pomerol (1980) said that :

> "by the close of Hercynian times France was entirely cratonized except in the south-east"

The process of cratonization is pehaps more readily understood from Germany where a series of tectonic divisions was recognised by Kossmat (1927). From North to South (Fig. 2) these are :

1 Rhenohercynian

2 Saxothuringian

3 Moldanubian

To the north lies a succession of ORS and Carboniferous rocks formed on a passive margin of a northern land mass. The sediments grade south from carbonates and shales to a turbidite-rich succession , which has been pushed northwards as a series of flysch nappes of the Hercynian. The Saxothuringian zone further south is of metamorphic rocks and igneous intrusions created by mid-palaeozoic subduction and late palaeozoic collision, Here are the cores of the main Hercynian nappes. The Moldanubian is of deeper metamorphic rocks of Precambrian age intruded by late Palaeozoic granites.

The structure suggested by Franke (1989) shows northward compression during the late Palaeozoic. (Fig. 3).

In the Swiss Alps there are resistant massifs (Aar, Auguilles Rouges etc) of early Hercynian amphibolite grade metamorphic rocks and granitic intrusions upon which rest small half graben basins containing late Carboniferous and early Permian molassic sediments. According to Trumpy (1980) the I-type granites, are between 360 and 260 Ma in age. Their origin in a cordilleran subduction environment indicates a NW ward subduction along the northern margin of proto-Tethys. The sedimentary basins are filled with varied sandstones, sometimes with coal, passing upwards into coarse conglomerates with bituminous and fish-bearing shales. Late - Hercynian deformation led to coal rank increasing to anthracite and graphitic schist locally. The closely folded and faulted sequences and metamorphic rocks were eroded before the unconformably overlying Triassic sediments accumulated. This semester the Dt de Morcles map for the SH class contains an example of such a basin.

Two major facies of deposition dominate the European successions:

The Germanic facies is predominantly of red beds. Initially, in the Bunter, these are red sandstones with pebble horizons near marginal uplands. The lower parts of the basins flooded during the Muschelkalk, when a shelf sea gave rise to limestones, dolomites and evaporites, the hypersaline conditions generating a fauna with low species deversity but big numbers of those represented, eg. *Ceratites* and *Terebratula*. Osmoregulatory pressures limited to organisms. Both dolomites and evaporites extend up into the Keuper before red mudrocks and fine sandstones complete the succession. There are no prolific fossils suitable for correlation and stratigraphic sequences are established on the basis of lithological variations in successions no more than 300m thick.

The Alpine facies begins with red beds, but is mainly of marine sediments, commonly several km thick. Fossils are abundant, so chronostratigraphic correlation is possible. Although the sediments are thick they are generally shallow marine deposits, not deep sea successions. There are none of the hypersdaline deposits typical of the Muschelkalk seas, but in the east reefal limestones develop on blocks surrounded by muddy deeper water sediments.

BUNTER (248-243 Ma)

The basal Triassic sediments sit on a late Permian surface which was dominated by a major river system draining SW-NE from the north of the Massif Central, through the Trier area and the Eifel towards Poland and beyond into Russia. In the Permian and early Trias it was low enough for occasional shallow influxes of the Tethyan sea, which proceeded to dry out in a series of desiccation cycles. Around this sea the uplands were undergoing destruction by the rivers which carried sands into the low ground, generally producing successions of red fluvial sandstones and red mudstones. Commonly the earliest Triassic material has darkly coloured pebbles of clay within the sands, producing a spotted rock referred to as Tigersandstein.

Using sedimentary structures it is possible to reconstruct the river patterns draining from the nearby highlands (Madler, 1985), using both current bedding and pebble types as tracers for origin of the materials. Around the margins of the basin there were long periods of non-deposition, marked by well developed soil profiles, often retaining horizonation. Known as Violette Grenz zonen (VG), they are often associated with thin dolomitic breccias probably from former caliche layers, hard pans virtually at the surface. Often continuous over considerable areas, these VG zones enable time correlation in otherwise pretty uniform rocks. Three main VGs plus small ones.

Two clear erosional surfaces occur towards the top of the Bunter, the Sollingen and Hardegsen unconformities, which are recognised best around the margins of the basins.

The problems of trying to stratigraphically subdivide substantial thinknesses of largely uniform and virtually unfossiliferous sediments are not trivial. Using the soil layers, changes in current bedding directions, pebble content etc all effectively invoke lithostratigraphic proceedures, which really give no guarantee that they have any real stratigraphic time significance. However it is often the best we can do in unfossiliferous units.

Magnetostratigraphic methods, using the dierction of the Earth’s magnetic field during formation of the diagenetic iron oxides, which give the pigmentation to the red beds enabled Burek (1970) to achieve some crude recognition of at least the position of the base of the Trias, and some form of stratigraphy for the units above (Fig. 4). Throughout the Permian the stable condition was predominantly one of reversed polarity (N magnetic pole in the S), but in the Buntsandstein part of the Trias there were many (17) alternations between normal and reversed polarity. After the end of the Scythian normality seems to have been the preferred field direction. So for spotting the base of the Trias within the red beds this is useful, but it is not very helpful in finding relative position within the Buntsandstein.

MUSCHELKALK (243 - 231 Ma)

At the end of the Scythian the sea flooded in from the east and south-east (across the Carpathians) to give open marine conditions with rich Tethyan faunas in carbonates to the east (about 500mthick here), but more restricted shallower waters generating dolomitic marls and evaporites to the west.

- 1.The basal Wellenkalk is alternations of deep water limestone with marls in the north and east, with sandier versions to the west, near the supposed shorelines.
- 2.The Anhydritgruppe is a western facies of lagoonal origin, comprising dolomites with gypsum, anhydrite and halite and with a few stunted fossils
- 3.The Hauptmuschelkalk (Muschelkalk s.s.) is an obviously open marine deposit with prolific fauna. At base is a crinoidal layer *Encrinus liliformis*, commonly used in the building industry. There are sandy banks and banks of limestone covered with Terebratula and coquinas with *Myophoria*, *Pecten* and *Hörnesia* . *Ceratites* occurs at the top of the Muschelkalk
- 4. In the Ladinian the connections to Tethys start to close and evaporites reappear, together with impoverished faunas. The Lettenkohle (=coal of clays) is the last deposit of the Muschelkalk sea, showing vertical changes from marine through lagoonal to freshwater and continental deposits. Germans say Lettenkohle is Keuper because of non-marine influence, French say it is Muschelkalk because of marine influence....

KEUPER (231 - 213 Ma)

Right at the end of the Ladinian the marine connection with Tethys was re-established through Germany and into France. Carbonate platforms of the open water areas passed laterally into dolomites and clays with local evaporites (gypsum and anhydrite). the red and green marls commonly seen in the Keuper in UK were widely developed in Germany.

In the north extensive alluvial fans extended from the Scandinavian high ground, across N. Germany and Denmark, burying the evaporitic sequences. Passing outwards from the fans are areas with red fine grained fluvial sandstones which often contain Equisetales, a horsetail with habit rather like the moder reed and interpreted here as marking oases or desert water courses, Reptilian remains are sometimes associated.

Summary

- During much of the Trias we had desert-like conditions stretching from Britain through Brittany, nearby Spain (not yet rotated to present position) across northern Germany and into Poland, down into Bohemia. All areas had very similar deposits.
- The shallow shelf seas of the Muschelkalk penetrated into central Germany, south through Provence and into southern Spain and even N.Africa.

In France the Germanic facies of the Trias extends eastwards into the Jura mountains, where the Buntsandstein is present at the base. This passes up into the very important gypsum and anhydrite (sulphate rich) evaporites of the Muschelkalk, which provide the surface of decollement above which the Jura folding develops. According to Trumpy (1980) the evaporites die out to NE and SE and as they do so the folding also dies out. They reappear in a few isolated basins within the Helvetic and pre-alpine successions of the higher alps.

In the alpine area suites of neighbouring facies of deposition are recognised from Triassic through the Jurassic. These belts are illustrated on Fig. 8. Their positions today are not quite as they were during deposition as a result of major sliding and overfolding along the Triassic anhydrite layers during the Alpine orogeny. We will discuss them as they were originally deposited (see the Gignoux reconstruction of Fig. 9).

- External zone (Helvetic of Switzerland and Dauphiné of France) A thin succession of continental shelf deposits starting with <100m of current bedded and rippled quartzites, followed by thin zones of cargneules, a coarsely cavernous dolomite. The caverns are often 1 cm and more across and are usually filled with brecciated evaporite or shaly material. This is the Muschelkalk equivalent, which also served later as a lubricant during orogeny. Above these are the ’schistes variolées’, variegated or multi-coloured shales.
- Valais belt is generally a narrow zone in the west, broadening eastwards. The Trias is even thinner here, but similar in facies sequence. This belt is more important in Jurassic and Cretaceous times.
- Sub-Briançonnais. A broad belt of more strongly marine affinity forming much of the northern Pennine nappe area (Gd St Bernard and Monte Rosa nappes). Much thicker, with basal quartzites over 200m followed by the variegated shales and cargneules passing into algal limestones and dolomites over 1000m thick. Sometimes anhydrites cap the succession.
- Piedmont Zone (Schistes lustrées zone) of S. Switzerland and N. Italy shows very similar but thinner Triassic sequence generally little metamorphosed, passing up into the former shales now the basis of the Liassic, schistes lustrées, which form envelopes to the major folded nappes of the Pennine Alps. Interesting rocks which show garnets and staurolites beside belemnites and ammonites....
- Austro-Alpine and S.Alpine area. Some of the most famous Triassic sediments showing a combination of deep water successions with intervening shallow water reefal limestones perched on faulted blocks. Basal sandstones pass up into deep water limestones with a good cephalopod fauna (*Ptychites*, *Monophyllites*, etc) followed by the shale and reefal limestone pairing (rather as in the block and basin patterns of the L. Carb in N. England). Later still the waters shallowed so that in the Keuper brackishwater organisms like*Estheria* are found. Right at the end we find a dolomite and reef assemblage of shallow marine origin.
- S.Alps and Dolomites. Again the carbonates start with the Muschelkalk and three distinct facies are recognised:

a) ’Normal’ facies. Shales and thin limestones with occasional tuffs. In the Dolomite Mountains proper masses of basic volcanics, lavas and tuffs with deep water pelagic fauna (radiolarites) between. Plants from Volcanic islands?

b) Poorly bedded dolomites and limestones of reefal facies eg Marmolata Lsts, mainly of calcareous algae

c) Euxenic facies. Black bituminous lsts and dolomites and shales. Very like later Jurassic black shales with rich, well preserved fauna including swimming reptiles. No known bottom fauns--no oxygen in deep stagnant basins.

It appears that the adjacent facies were related to sites on a parallel series of tilted half-graben structures associated with extensional tectonics of a passive margin to the northern continent. Within the margins of Tethys the shallow water areas gave reefal conditions and deeper waters were present in the intervening strips. Today this gives rise to fault-delimited bands of massive cliffs of limestone surrounded by lush pastures developed on the volcanics and shales of the deeper water areas.

This very brief review is intended to provide a little geotourism around Europe during one phase of the development of the continent, while the ocean of Tethys was starting to exert its influence. As the first period of the Mesozoic the Trias was important in marking the resurgence after the elimination of much of the Palaeozoic fauna. With the formation of the new Tethyan ocean fresh shelf area appeared and a great range of possibilities for experimentation with new environments became available to the survivors. Opportunistic species thrived and within the 35 Ma major new faunal elements appeared. From the European scene there was little chance to diversify heavily onto the land surface, because deserts do not lend themselves to ready colonisation, bur in the sea it was a very different story.

However, despite the diversification which occurred during the Trias there was a further abrupt series of changes to the fauna and flora, with moremass extinctions at the end of the period. The reasons for this drastic Triassic-Jurassic break have stimulated a lot of discussion, with many workers suggesting that a bolide collision may have been responsible, much as that more popularly known one which has been partly blamed for the elimination of the dinosaurs at the end of the Cretaceous.

Currently popular with film-makers, what should the geologist seek to confirm that such an event did occur?

- presence of a layer of ’shocked’ quartz, individual grains showing many sets of fractures produced by impacts.
- presence of many glassy meteorites the tektites commonly reported from such boundary zones
- presence of a geochemical anomaly with unusually high iridium concentrations. This element is not common on earth but shows far higher concentrations in meteorites.
- Suitably timed impact crater ?
- Very sharply defined faunal or flora break ?

Do we have these at the end of the Trias?

- impact flaws in quartz crystals are know froma 5cm thick layer at the Trias-Jurassic boundary in N. Italy.
- no tektites as yet reported from this level
- no evidence yet confirmed of an iridium anomaly
- There is one supposed impact crater at Manicouagan in Quebec Province, Canada. Crater about 60km across of about the right age
- Towards the end of the Trias there was good evidence from Virginia and New Jersey of regular cyclical changes of sea level, giving cycles of sediment change. Each cycle is thought to have lasted about 21 000a. In each regular patterns of floral and faunal changes. Cycles continue into the L.Jurassic, but in one cycle most of Triassic types vanish. In pollen terms only ferns and lycopods remain, and today they are known to have the ability to survive for long periods before rejenerating.

The jury is out, with a present score of about 50 : 50 on the outcome.

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