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**The Graptolitic Faunas of the Gotlandian in the Eastern Alps and their Relationships.**

By Professor FRANZ HERITSCH (Graz).

THE years that followed the Great War saw a rapid development in knowledge of the graptolitic faunas of the Eastern Alps. Professor M. Gortani described many graptolites from the Carnic Alps, and papers from the Geological Department of the University of Graz dealt with the same subject, as well as the distribution of the graptolites over a wider area of the Eastern Alps. Especially

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noteworthy was the surprising discovery of graptolites in the so-called grauwacke zone of the Alps, which follows the southern margin of the Northern Calcareous Alps. In the grauwacke zone, which consists of Palaeozoic and more ancient strata, more or less metamorphosed, graptolites were found at the following localities, (a) Fieberbrunn in the Tyrol (1),<sup>1</sup> where the zones of *Monograptus cyphus* to *M. turriculatus* are found, and the presence of *M. priodon* indicates that higher zones may occur; (b) environs of Eisenerz in Styria (2), where the zones of *M. gregarius* to *M. griestoniensis* are found, as well as the zone of *M. nilssoni*; (c) Montavon in Vorarlberg (29), where a badly-preserved specimen of *Monograptus*, possibly *M. priodon*, was discovered.

*Rastrites* sp. has been found in the Palaeozoic region of Graz, in the lydites and black siliceous rocks which are of rare occurrence. Also, from the black siliceous shales of Murau, in the valley of the Mur, *Rastrites* sp., *Monograptus* sp., and *Diplograptus* sp. have been recorded (4).

These recent discoveries in the grauwacke zone and in the neighbourhood of Graz and Murau suggest that Gotlandian graptolites may be widespread in the Palaeozoic regions of the Eastern Alps. It is worthy of note, too, that Ordovician graptolites have been found at four localities in the grauwacke zone.

The first discovery of graptolites in the Carnic Alps was made sixty years ago by G. Stache (5), but it was not until the post-war years that detailed studies of the graptolitic faunas were undertaken, notably by M. Gortani (6). That investigator showed that important faunas of Birkhill-Gala<sup>2</sup> age are present, many of the species being found in Great Britain. He recorded some new varieties. The faunas of Wenlock age in the Carnic Alps include many species occurring in England (*M. vomerinus* Nich. and its variety *gracilis* Elles and Wood, *Cyrtograptus murchisoni* Carr., and *C. carruthersi* Lapw.), and one Sardinian species (*M. hemipristis* Meneghini). In addition, Gortani has demonstrated that the zone of *M. nilssoni* is present. But Gortani's results do not tell the whole story, for many of the graptolites were not collected in situ, with the result that the faunas of different horizons have not been differentiated. It is not surprising, therefore, that he concluded that the zonal system of Elles and Wood was not applicable to the Carnic Alps (for example, Gortani cited, as from the Wenlock fauna of the Dellacher Alp, *M. remotus* Elles and Wood, which occurs in the zone of *M. turriculatus*).

More recent work by E. Haberfelner (7), has shown that the distribution of the graptolitic faunas is in accord with the zonal succession of Elles and Wood. Investigations by Haberfelner, and also by another of my students, Ida Peltzmann, accounts of which

<sup>1</sup> Numbers in parentheses refer to the Bibliography at the end of this paper.

<sup>2</sup> The term Birkhill-Gala is used as indicating the graptolitic facies of the Lower and Upper Valentian.

will shortly be published, show that graptolites characteristic of the zones from *Mesograptus modestus* (or perhaps *Akidograptus acuminatus*) to *M. leintwardinensis* are present. Moreover, Haberfelner has found *M. kayseri* and *M. hercynicus*, which belong to the stage of *ey* of Bohemia (= lowest Devonian).

Although most of the graptolites known from the Carnic Alps have been found in Britain, there occur also species recorded from Bohemia and Scandinavia. It is interesting to note the presence of the genus *Stomatograptus*, not known in Britain. Moreover, the finding of Sardinian species in the Carnic Alps is of great significance. As examples may be cited *M. sardous* Gortani, *M. proboscoidatus* Gortani, and *M. tariccoi* Gortani, from the Wenlock. I. Peltzmann has found that species of Sardinian character appear, indeed, as early as the time of the *M. griestoniensis* zone of the Gala. These species are similar to, but not identical with, the forms described by Bouček (8) from Bohemia. The true Sardinian species first appear in the zone of *Cyrtograptus murchisoni* (*M. proboscoidatus* and *M. tariccoi*).

In all the graptolitic regions of the Alps, with one exception, the lowest zone of the Gotlandian (that of *Akidogr. acuminatus*) is missing. The exception is the Bischofalm Nappe in the Carnic Alps, in which the succession of Ordovician and Gotlandian rocks is complete.

In Bohemia, Bouček (9) has established zonal subdivisions between the beds which correspond to the zones of *M. crispus* and *M. riccartonensis* of the English succession. In these graptolite-bearing deposits, two species of Sardinian character appear, namely, *M. vomerinus* Nich. var. *robustus* Bouček (cf. *M. sardous* var. *eximius* Gortani) and *M. probosciformis* Bouček (cf. *M. mutuliferus* Gortani). Bouček (10) has also described a succession of shales and diabases of Valentian age in which occur graptolitic faunas of British type. The shales include the zone of *M. convolutus*, with graptolites known to occur only in England, and the zones of *M. turriculatus*, *M. crispus* and *M. griestoniensis*, in which most of the species are identical with those in the corresponding English faunas. The zone of *M. turriculatus* is here of considerable thickness; it is also thick and of wide extent in the Carnic Alps. Thus in Bohemia are found English and Scandinavian species in addition to purely Bohemian species, and in the Gala series, Sardinian forms.

The graptolitic faunas of the Balkan Mountains have been made known through the work of Allahverdijew, Bonev and Haberfelner (11). The Birkhill-Gala, Wenlock, and Ludlow are said to be present, the Wenlock containing graptolites of the English, Bohemian and Scandinavian faunas, together with six Sardinian species.

We owe our knowledge of the beautiful preserved graptolites of Sardinia to the excellent work of Gortani (12). Both the Birkhill

and Wenlock (the latter including *Cyrt. rigidus* Tullberg and many Sardinian species) have been recognized, but faunas of Gala age have unfortunately not yet been found. It is therefore not possible to say whether or not the Sardinian area was a part of the Alpine and Bohemian Sea in Gala times. While species restricted to Sardinia are very abundant in the Wenlock, other species of *Monograptus* are few.

A review of the faunas in Spain and Portugal indicates that many difficulties remain to be solved. A rich fauna has been described from Birkhill Shales of Almaden (13), also graptolites of Birkhill-Gala age from the Hesperid Mountains (14), a Birkhill fauna from the Cantabrian Mountains (15), and faunas from the Pyrenees (27). But no Sardinian forms have been recorded from these localities.

A list of graptolites from near Barcelona, ranging from Birkhill to Ludlow forms, has been published by Schriell (16). All of these have been recorded from Britain, but in the collections of the Geological Department of the University of Graz are pieces of greyish-black siliceous shales from Vileta (Barcelona) with *M. dubius* Suess, *M. colonus* Barr., *M. roemeri* Barr., and one with *M. tariccoi*. Thus it would appear that at least one Sardinian species does occur in Spain.

The work of Delgado (28) on the occurrence of Sardinian forms in Portugal is important. His work shows that in the region of Villarinho de Cima the succession includes the zones from *M. gregarius* to *M. crispus*, species of *Monograptus* being frequent, with two species of *Diplograptus* and two of *Rastrites*. In addition he records *M. cf. lamarmorae* Meneghini and *M. cf. gonii* Meneghini, and mentions eleven species of *Monograptus* "que nous considérons toutes nouvelles . . . Plusieurs de ces espèces sont remarquables par leurs énormes dimensions, les empreintes parvenant à atteindre 1 centimètre de largeur; elles le sont aussi par le nombre des cellules qui s'élèvent quelquefois à plus de 20, et d'autres fois descend jusqu'à 3 ou 4 en 1 centimètre de longueur de l'hydrosome". There is little doubt that these are Sardinian forms.

The presence of Sardinian species in Spain and Portugal makes it probable, in my opinion, that the Sardinian graptolite sea extended into the region of the Iberian peninsula. It is remarkable, however, that at Villarinho de Cima, the presence of the greater part of the Gala has not been established on graptolite evidence.

Surveying the graptolitic faunas of Europe, we are able to set out the following conclusions:—

1. The graptolitic faunas of Lower Valentian age are of the same type throughout the whole of Europe, and the species are those characteristic of the Birkhill Shales in Great Britain.

2. The differentiation begins in the Gala.

(a) In Scandinavia, particular species of the *vomerinus* group appear, e.g. *M. personatus* Tullberg and *M. linnarssoni* Tullberg;

with these species is associated *M. spinulosus* Tullberg, a spinose form which differs considerably from those of the *vomerinus* group. It is noteworthy that none of these three species is found in Great Britain, but one variety of *M. linnarssoni* (var. *flumendosa* Gortani) belongs to the Sardinian assemblage.

(b) In Bohemia the first Sardinian graptolites appear in the Gala.

(c) Similarly, Sardinian forms first appear in the zone of *M. griestoniensis* in the Carnic Alps.

3. The graptolitic faunas of the Wenlock of the Alps, Sardinia, and Bohemia differ considerably from those of Britain as a result of the presence of the Sardinian species. Light is thrown on the notable appearance of *Cyrtograptus* in the Wenlock by the work of Haberfelner (17), who believes that the genus takes its origin from *Monograptus*.

4. The graptolitic faunas of the Ludlow are similar over the whole of Europe.

The above conclusions help us to a realization of the palaeogeography of the graptolitic seas of Europe. The Nestor of graptolite investigators, Professor J. E. Marr, published a sketch-map of the area of deposition of the Stockdale Shales in Europe (18), which shows a deep gulf extending from the Atlantic Ocean across Great Britain into Scandinavia and Central Europe. Marr says, "In the quiet waters of such gulfs the fine sediments of the Stockdale Shales and their equivalents might well be formed, and the floating vegetation collected." Some features shown by the sketch-map are, (a) the gulf reaching from Scotland to the northern coast of Scandinavia, (b) the very great extension of the sea in south-eastern England, Germany, Bohemia, Sweden, and the Baltic provinces, (c) a peninsula between this great sea and the Mediterranean, comprising the area of the Alps and the southern part of France—a part of a great eastern continent.

But we now know that there was a sea between Bohemia and Sardinia. The graptolitic series of the Alps suggests that this sea connected the German and Mediterranean areas. All the regions with graptolitic shales were in communication in Lower Valentian time, but in the Upper Valentian this connection was not so complete between Germany and Bohemia, and between the Alps and Germany. In the Wenlock, open-sea conditions only existed between Bohemia, the Alps and Sardinia, while there was a bank interrupted by shallows, or a narrow chain of islands which in part prevented the intermingling of faunas, between this region and that of Great Britain and Germany. In the Ludlow, this bank or chain disappeared; free communication was possible once more between all the graptolitic regions of Europe.

We are forced to the conclusion that the Western Alps formed an island, for there were marine conditions in southern France as shown by the presence of the graptolitic series of the Montagne Noire, with Wenlock and Ludlow forms.

The graptolitic shales of Morocco belong to the Gotlandian Mediterranean Sea. The first graptolites were obtained by Gentil (19) from the lower part of the Gotlandian. P. Russo (20) has recently compiled a list of all the species found there.

The Gotlandian Mediterranean extended as far as Arabia, where Blanckenhorn (21) recorded some badly preserved graptolites. Also Frech, in his account of the geology of Asia Minor (22), states (p. 209) that "Obersilurische Graptolithenschiefer von der Hedshas Bahn (28° 20' n. Br., 36° 48' ö. L. Greenwich) erinnern an ähnliche Vorkommen Sardiniens".

The Gotlandian is not known to occur in Yugoslavia, Albania, and Greece, but rocks of Ordovician age have recently been proved by Desio (23) to occur in the island of Chios. As Devonian rocks are widely distributed in Asia Minor and in the region of the Bosphorus, and as there are limestones with *Halysites* recorded from the last-mentioned region, we may hope that the discovery of Gotlandian, possibly graptolite-bearing, will be made in due course.

The eastern continuation of the Mediterranean region of the graptolite sea included the area of the Balkan Mountains, but in the Caucasus the Gotlandian contains a non-graptolitic fauna which closely resembles the Bohemian fauna described by J. Barrande. But communication between the Caucasus and Bohemian Gotlandian seas could not have been directly east and west, because the Podolian Gotlandian of the northern (Baltic) facies is interposed. The connection can only have been by way of the Alpine area and the Mediterranean Gotlandian.

Graptolitic faunas indicating the occurrence of the zones from that of *M. cyphus* to *M. griestoniensis* (excepting *M. convolutus*), and *M. nilssoni*, *M. scanicus* and *M. leintwardinensis* have been found in the southern part of the Urals. Sardinian forms have not yet been recorded from this region. Passing to Eastern Turkestan, B. Averianow (26) has produced evidence of graptolitic faunas of Birkhill Gala, Wenlock, and Ludlow age. Most of the graptolites are known from Great Britain. Averianow has described a new species, *M. ferganensis*, from the Gala, which is very broad (3.5 to 4 mm.) and has a small number of thecae (5 to 6 in 10 mm.). It appears to be of Sardinian character. Probably, a variety of *M. vomerinus*, named by Averianow, var. *major*, also belongs to that group. These records suggest that the graptolitic region of Turkestan was an extension of the Mediterranean.

If we may venture to generalize, it seems that the evolution of Sardinian forms took place in those regions which show the Bohemian facies (Barrandian) of the Gotlandian. The problem of whether the Sardinian forms have evolved from the English species or whether they migrated from other regions cannot at present be solved, but it seems probable that the former is the true explanation.

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