



IGCP Project 469

IGCP 469 – Late Westphalian terrestrial biotas and environments of the Variscan Foreland and adjacent intramontane basins

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Кристофер Клиил — Проект IGCP 469 — Поздневестфальские континентальные биоты и обстановки варисцийского фторланда и соседних межгорных бассейнов. Задача этого пятилетнего проекта — исследовать палеоэкологические изменения в Европе и Северной Америке в связи с варисцийским орогенезом (поздний вестфаль — ранний стейфан). В частности внимание будет сосредоточено на картину вымирания палеотропических болот в низких частях рельефа и на развитие межгорных бассейнов в соседних варисцийских горных цепях. Проект объединит седиментологические и палеонтологические данные. Будет сделано обобщение и сравнение информации по седиментологическим изменениям в отдельных бассейнах. Акцент будет поставлен на изменения, связанные с дренированием вод и с изменениями их уровня. Для каждого из основных поздневестфальских и раннестейфанских каменноугольных бассейнов в исследованном регионе будет изготовлена обобщенная база данных. При этом будет применяться поливариантный статистический анализ. Палинологические данные будут использованы для исследования общих изменений палеотропической растительности. Континентальная фауна этого периода весьма ограничена, но при наличии соответствующих палеозоологических данных, в особенности о насекомых, о членистоногих и о червях (в том числе и их следов), тоже будет включена в обобщения. Ожидаемый синтез даст возможность получить наиболее полную картину палеоэкологической обстановки на территориях, испытавших влияние варисцийского орогенеза, и будет иметь важное значение для понимания его эволюции.

Abstract. This five-year project is to investigate the palaeoecological changes in Europe and North America that resulted from the Variscan Orogeny (late Westphalian-early Stephanian). In particular, we will be looking at the pattern of disruption to the lowland palaeotropical swamp habitats and the development of intramontane basins within the adjoining Variscan Mountains. The project will integrate data from the sedimentological and fossil record. Evidence of sedimentological changes that took place in the different basins will be collated and compared, especially those changes that affected drainage patterns and water-table levels. An integrated palaeofloristic database is to be developed for each of the main late Westphalian and earliest Stephanian coal basins in the study area, and investigated by multivariate statistical analysis. Palynology will be used to investigate overall changes in the palaeotropical vegetation. Terrestrial faunas of this age are on the whole limited, but where available we will integrate palaeozoological data, especially from insects, arachnids and vertebrates (including tracks). The resulting synthesis will provide the most complete environmental picture to date of these Variscan-affected habitats, and will have important consequences for our understanding of the evolution of the Variscan Orogeny.

Cleal, C.J., 2004. IGCP 469 – Late Westphalian terrestrial biotas and environments of the Variscan Foreland and adjacent intramontane basins. — *Geologica Balc.*, 34, 1-2; 3-10.

Key words: Carboniferous, macrofloras, palynology, macrofaunas, sedimentology.

Introduction

The Variscan Orogeny resulted from the closure of the Rheic Ocean, as the Gondwana and Laurussia plates collided during the Pennsylvanian (Late Carboniferous) Subperiod. It was one of the three major Phanerozoic orogenies in Europe and eastern North America, and is thus critical for our overall geological understanding of the region. It also had a major impact on the contemporaneous environment, as it resulted in a tract of lowlands developing adjacent to the plate-suture (Fig. 1). These palaeotropical lowlands became densely vegetated by lycophyte dominated swamp forests (known as the Coal Forests), which generated thick peat deposits that later changed into coal. For most of the early Westphalian Epoch (c. 316 – 311 Ma – chronology according to Menning et al. 2000 Times Scale B), conditions across this plain were relatively stable, the only significant disturbance being due to periodic eustatic flooding (Calver, 1968). However, in the late Westphalian (c. 305 – 311 Ma) Variscan tectonic activity caused instability in the area, which started to break up into a series of separate basins, which seemed to have differed from each other in elevation, sedimentary regime, drainage patterns, and vegetation.

Development of the Project

Much attention has been given to the tectonic history of the Variscan Orogen and how this affects our understanding of the observable geology of these areas (e.g. Kossmat, 1927; Franke et al., 2000). However, less attention has been given to how it impacted on the environment and biotas of the time. If a comparable event occurred today, it would undoubtedly be regarded as a major ecological catastrophe, resulting in significant changes in local biodiversity, and charting these changes has an intrinsic interest for palaeontologists and geologists. Understanding the factors influencing peat-development here also has potentially significant economic consequence. Although coal has recently declined in importance as an energy resource in Europe and North America, as oil and gas reserves diminish, coal may again become important. Understanding how the Pennsylvanian coals were formed and what affected their distribution, will be vital to their efficient exploitation in the future.

It has also recently become evident that these events in the Pennsylvanian Subperiod may help us understand modern-day environmental changes, as it is the only other pre-Quaternary time when global conditions were comparable to what

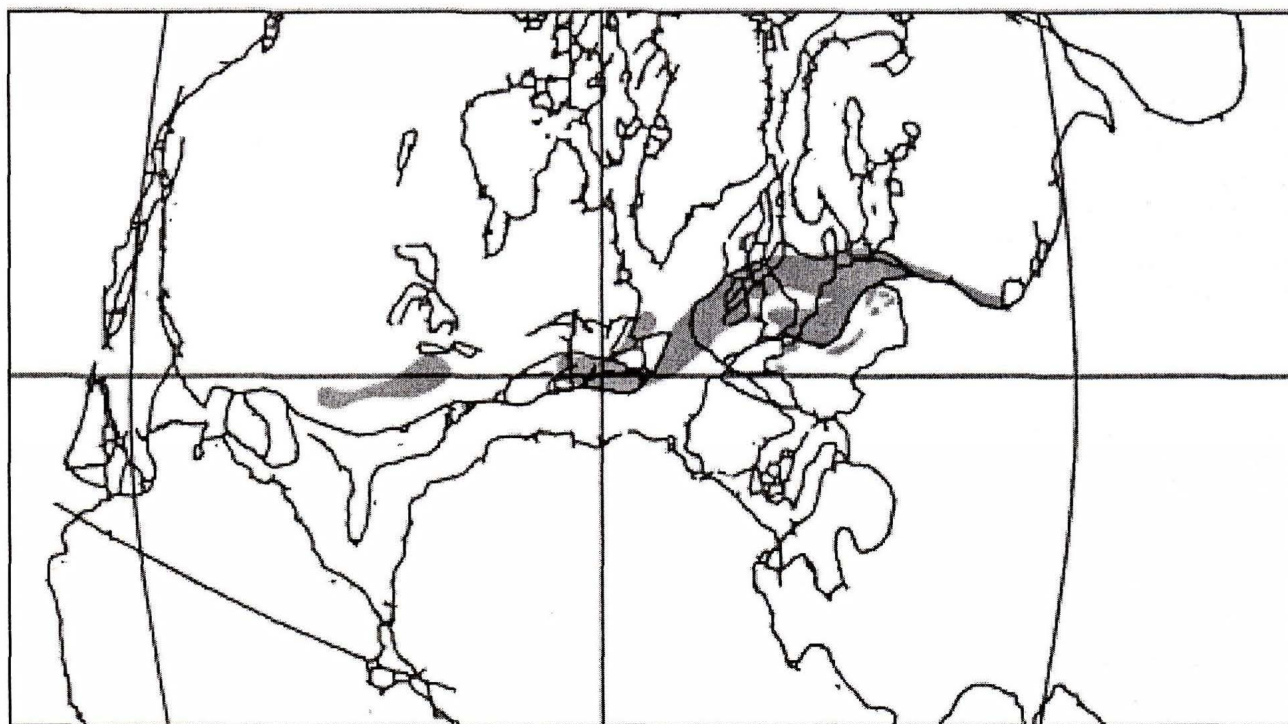


Fig. 1. Distribution of coal forests during the late Westphalian in Europe and North America. Based on a base map by Scotese (1986), with the distribution of the forests adapted from Haszeldine (1984) and Calder (1998)

we have today (Gastaldo et al., 1996, Cleal and Thomas, 1999). In particular, it may help us understand the interrelationship between tropical forests, atmospheric CO₂, and global climates. The Variscan Orogeny had a significant impact on the Pennsylvanian tropical forests. Did this have any wider-reaching impacts on the global environment?

This is of course not the first attempt to synthesise the palaeontology and sedimentology from across the Variscan region. However, previous attempts have tended to be made by individual scientists, combining their own experiences obtained when visiting other coal-basins and collections, with evidence from the literature. Whilst such studies have undoubtedly brought some insights to the problem, they have not proved totally successful for mainly practical reasons. The experience necessary for the proper understanding of the palaeontology and sedimentology of a coal-basin is difficult to obtain by an outside expert from just a short visit; only the local expert will have that experience. On the other hand, just collating data from the literature can encounter problems of uneven nomenclature used in different countries.

IGCP 469 aims to overcome some of these problems by bringing together a team of specialists from across the Variscan area. The philosophy behind the project was developed during a collaborative project funded as part of the NATO Science Programme, which involved palaeobotanists from Canada, the United Kingdom and Bulgaria. It gave us the opportunity to visit each other's collections, and discuss issues of taxonomy and palaeoecology, and gave greater insight into the development of vegetation across the Variscan Foreland than could have been obtained if we were operating independently. We therefore decided to expand the project geographically, to include other coal basins, both from the Foreland itself and the associated intramontane basins. We also expanded it to include evidence from terrestrial faunas and sedimentology, to obtain a more complete picture of the environmental changes taking place.

It is not our intention for the whole team to study all of the palaeontology and sedimentology from across this area. Rather, it is to allow discussions between the various team-members, to see where the conceptual and nomenclatural disagreements can be resolved. This should allow us to develop sets of data from the different coal-basins, that are of consistent format, and use consistent terminology and taxonomic nomenclature, and thus allow a meaningful synthesis to be made.

Objectives of the project

The following objectives have been established in order to achieve an overall understanding of the environmental changes that took place in the Pennsylvanian equatorial Coal Forests.

- Development of a comprehensive biodiversity inventory of the biota of the clastic-substrate habitats as preserved in the adpression record (*sensu* Shute and Cleal, 1986) in the different coal basins in the region.
- Investigation of this inventory using multivariate techniques to establish biogeographical patterns within the region.
- Determine patterns of biodiversity change in these habitats.
- Identification of chronological changes in the regional composition of the vegetation, principally by looking at the palynology.
- Comparison of the sedimentology of the different coal basins, to establish what physical constraints were to the development of the Coal Forest vegetation.
- Estimation of the coal reserves that originally existed and now exist in this area. The former will give some idea as to the carbon down draw represented by these forests; the latter will give some idea as to the future potential of these coals as an energy resource.
- An improved biostratigraphical resolution across the Moscovian-Kasimovian GSSP in terrestrial facies.
- A clearer understanding of the topographic changes taking place across the Variscan Foreland and Mountains during the late Westphalian and early Stephanian, and how this relates to the tectonics of the Variscan Orogeny.
- Establishing a geoconservation strategy for these deposits, with the possibility of developing geotourism.

In the first instance, the work will be limited to eastern North America, and northern, central and eastern Europe. The more heavily marine-influenced basins such as the Cantabrian Mountains (Spain), Illinois (USA) and the Donets (Ukraine) tended to have somewhat different vegetation and were subjected to different tectonic influences. By restricting the work to the mainly non-marine sequences of the Variscan Foreland and the intramontane basins of the Variscan Mountains, the project will therefore have a more sharply focused remit. Nevertheless, there is clearly the potential for extending the work into these other areas at a later date.

Vegetation biodiversity inventories

Vegetation is generally recognised as one of the most sensitive indicators of environmental change in modern terrestrial habitats (e.g. Birks and Birks, 1980). It is likely, therefore, that the palaeobotanical record will be the best means of interpreting the evolution of terrestrial environments in these Variscan habitats. The main problem is that plant macrofossils give only a very partial record of the vegetation in the Coal Forests, mainly of the plants growing on the physically raised, clastic-rich substrates, especially of the river-levees (e.g. Gastaldo, 1985, Cleal and Thomas, 1994). These formed only a very small part of the plant-mass represented by the Coal Forests, most of which comprised the water-logged, lycophyte-dominated back swamp vegetation. Great care must therefore be taken when trying to make palaeoecological interpretations of the Coal Forests from the adpression record. Nevertheless, provided there is a consistency in comparing floras from comparable facies, it is possible to use the adpression record for palaeofloristic work.

Establishing reliable and consistent biodiversity inventories for the different coal basins obviously requires a consistent taxonomy for the plant species. Despite over two centuries of investigation on these floras, there is still a remarkable degree of inconsistency in the taxonomy being used by palaeobotanists in different countries. This is a major problem that must be overcome if the inventories are to be compared. To achieve this, a series of workshops will be held in the principal centres for palaeobotanical collections from the main late Westphalian coal basins. This will bring together specialists in the taxonomy of various plant groups with local palaeobotanists who are familiar with the fossil floras in their particular areas. The meetings will facilitate, where necessary, systematic revisions of the plants in the different basins in order to achieve the consistency in taxonomy that the project requires. When we say that a particular species occurs in area 1 and area 2, we will be confident that we are talking about the same species.

Palaeofloristics

Provincialism in the late Westphalian floras of Europe and North America has been identified by a number of authors, most notably by Gothan (1951, 1954) based on his extensive experience of the European fossil floras (see also Tenchov, 1975). Gothan's wide-ranging reviews of the adpression floras of this age suggest that there were

clear differences in the vegetation between the different basins, especially between the lowland areas of the Variscan Foreland and the intramontane basins of the Variscan Mountains. However, because they were such wide-ranging reviews, the empirical systematic evidence on which they were based could rarely be documented in the papers. More focused studies on specific plant groups, such as on *Sphenophyllum* (Storch, 1980), the neuropteroides (Cleal and Shute, 1995), and *Neuralethopteris* (Goubet et al. 2000) were able to present the data on which the analyses were based, and seemed broadly to support Gothan's thesis of provincialism in Pennsylvanian vegetation. However, only a small number of plant groups have so far been the subject of such focused studies, and other authors have expressed doubt as to the level of vegetational provincialism in these floras (e.g. Laveine, 1977).

Analysing the biodiversity inventories for floristic patterns can be done in various ways, but experience from studies of Mesozoic floristics suggests that ordination analysis is one of the more potent tools. Such a statistical approach has not been attempted in the Pennsylvanian, except for a preliminary broad-brush analysis that was based on an uncritical collation of earlier taxonomic lists (Rowley et al., 1985). In the present project, we therefore intend to include specialists in this type of analysis that have previously concentrated on geologically younger floras. In this way, we can investigate the floristic database that has been developed using a consistent taxonomy, using the best available methods of analysis.

Palynology

As noted earlier, the adpression record in the clastic deposits reflects only a very small part of the Coal Forests vegetation. For mainly biostratigraphic reasons, remains of the lycophyte dominated backswamp vegetation rarely found its way into the flood basin lakes, where most of the finer-grained clastic sediment was deposited (Fielding, 1984; for a modern analogue, see Gastaldo et al., 1987). If we are to understand the vegetation of the greater part of the Coal Forests, we have to examine different sources of data.

The coal ball record, which provides anatomical preservation of plant remains within the coals, is probably the best means of approaching this problem (e.g. DiMichele et al., 1985, DiMichele and Phillips, 1994, Phillips and DiMichele, 1998). However, coal balls normally only occur when there is marine influence (Scott and Rex, 1985) and the area to be covered in this study is virtually void of marine conditions except for

some brief transgressions during early Bolsovian times (Calver, 1968).

The only other approach to this problem is palynology (linked with coal petrography). Pollen and spores preserved within the coals provide evidence of a markedly different type of vegetation to that preserved in the adpression record of the clastic strata (e.g. Smith, 1962) and probably represent mainly the local vegetation of the back swamps (e.g. compare Jackson, 1994). A combination of problems (phylogenetic convergence, pollen/spore ontogeny, infraspecific variation) makes it difficult to give an exact correlation between the palynological record and the sorts of morphospecies identifiable in the adpression record. Nevertheless, palynology is potentially an important tool for identifying changes in the broad composition of the vegetation (e.g. Smith, 1957, 1962, Phillips et al., 1985). It also provides important insights into how the vegetation varied in composition across the swamp, and its relationship to factors such as precipitation. Where there is a good palynological record from the coals, this will be taken into account, such as in Saar-Lorraine (e.g. Alpern et al., 1967), Central Bohemia (e.g. Opluštil et al., 1999), the Dobrudzha Coalfield (Lacheva and Dimitrova, 1984, Dimitrova, 1997), and the Sydney Coalfield (e.g. Hacquebard, 1997).

Recent studies have also shown that palynology can be used to obtain an understanding of overall composition of the forests. There is now sufficient evidence from *in situ* pollen and spores (e.g. Balme, 1995; Bek and Opluštil, 1998) for us to relate most palynological morphogenera to their parent plant orders, and often families. Coal palynology tends to be heavily influenced by very local changes in the vegetation, but the palynology of the clastic deposits provides a much broader sample of the vegetation of the Coal Forests. The project will therefore aim to encourage further studies of this type across the research area.

Faunas

There are virtually no marine deposits within the sequences to be studied, and so evidence from marine faunas obviously cannot be incorporated within the project. Most terrestrial faunas were still relatively restricted in diversity and abundance in the Pennsylvanian. The most widespread are body-fossils of insects and spiders, and trace fossils of vertebrates, but there have been few attempts at regional studies of their biogeography. The project will, therefore, aim to develop a database of the distribution of these fossils across the Variscan Foreland and Mountains, and

to use this to establish biogeographical patterns for these groups.

Non-marine bivalves have traditionally been an integral part of the study of these deposits, both for biostratigraphy and palaeoecology. However, there are currently no active specialists in this field in Europe, so we have restricted the study to terrestrial faunas.

Biostratigraphy and correlation

Comparisons of both the adpression and palynological records will clearly only be meaningful if they can be done in a robust chronological context; it is essential that we compare floras of similar ages. The difficulty is that the most detailed biostratigraphical work on these deposits is based on the macrofloras (e.g. Cleal, 1978, 1984a, 1984b, 1986, 1987, 1991, 1997; Kotasowa, 1979; Wagner et al., 1983; Zodrow, 1986; Wagner and Alvarez-Vázquez, 1991; Kotasowa and Migier, 1995) and there is clearly great potential for circular argument. It will, therefore, be essential that we re-examine the basis of the biostratigraphy on which these correlations are made. This will also enable us to compare the floristic results within the region being studied with evidence from other areas (e.g. northern Spain, North Africa, Ukraine, Turkey).

This part of the stratigraphical column is currently under renewed investigation as part of the search for a stratotype for the proposed Moscovian-Kasimovian GSSP (Villa, 2002). Although this GSSP is to be defined in a marine sequence, its effectiveness as a chronostratigraphical boundary will be enhanced if it can also be identified in non-marine sequences, such as those being studied in the presently proposed project. The improved macrofloral and palynological biostratigraphical data that we hope to collate will hopefully improve correlations with the mixed marine – non-marine sequences in the Donets and northern Spain, which in turn should allow the GSSP to be located in the exclusively non-marine Variscan area.

Sedimentary environments

Sedimentology provides a direct insight into aspects of the physical environment of the time, especially those relating to substrate and water-table levels. This can be at the 'broad-brush' level, of looking at the changes between grey coal-bearing facies, to red-bed facies, to alluvial sandstone facies, which can help us understand regional topographic changes taking place in response to

Variscan tectonics. It can also be at the level of examining the details of drainage patterns within basins (e.g. Tenchov, 1993), which can also change in response to tectonic movement.

Sedimentology is also an important tool for helping understand the palaeontological record. It has been known for many years that the composition of fossil floras can vary according to the sedimentological facies in which they are preserved (e.g. Dräbert, 1964; Scott, 1978, 1979; Gastaldo, 1985). It has also been argued that the general sedimentary regime in a basin may affect the vegetation growing there (Tenchov, 1976). Integrating the palaeontological and sedimentological record will therefore be critical for developing a full understanding of what was happening to the environment at this time.

Geoconservation

Much of the area being covered by IGCP 469 has little rock exposure and a large part of the data has to be obtained from artificial workings such as underground coal mines, and from boreholes. This makes it all the more important that we identify those areas where there is outcrop and we look at the possibilities of trying to conserve the sites. In Europe, one of the best areas for this is southern Britain and some sites here are being actively conserved (Cleal and Thomas, 1996). Even here, though, it is clear that not all of the important sites meriting conservation have been identified.

Protecting this resource of geological information is of course of direct interest to the specialist geologists such as those involved in IGCP 469, but it is also of relevance to a wider community. Much of the research area has in recent years been suffering economically, as coal mining has declined and in many cases disappeared. These areas have been forced to develop new areas of economic activity, usually within the framework of sustainable development. Tourism could be developed partly to fill this gap in economic activity, although in many cases the coalfields may not be thought to have much to offer in this field. The one thing that some do have is their geological heritage and the historical mining heritage that goes with it. There is increasing awareness that geotourism can be developed to increase visitor-numbers to an area, especially through the development of Geoparks. IGCP 469 will keep this potential in mind when investigating the surface geology of the research area.

Conclusion

Much of this work could of course be carried out independently in the different countries, but bringing the national groups of specialists together will confer many benefits. There is the obvious advantage of allowing different approaches and interpretations to be compared in different geological settings. Perhaps the most significant advantage, however, is that it will help overcome the problem of regional differences that exist in scientific nomenclature, including palaeontological taxonomy. This inconsistency has been a major stumbling-block to making a proper synthesis of the available data, and is a problem which an international project such as this is ideally placed to overcome. Bringing together specialists from throughout the region will enable a consistent nomenclature to be developed, which can then be used in each country. Without such international collaboration, a meaningful biogeographical analysis becomes very difficult.

Acknowledgements. This paper is a contribution to IGCP 469 – *Late Variscan terrestrial biotas and palaeoenvironments*. The author is grateful to the Royal Society of London, for financial support for his visit to Sofia.

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