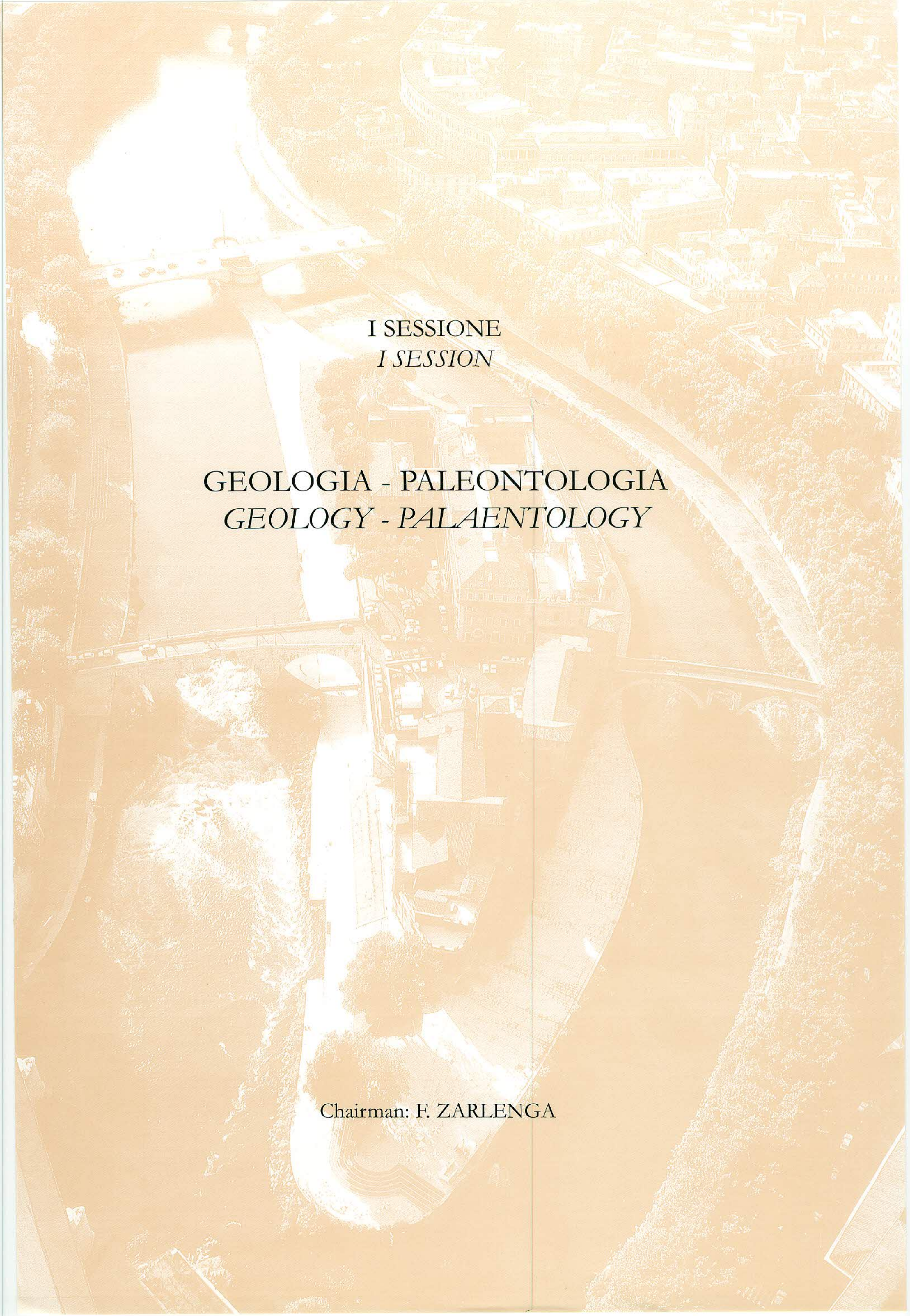

I SESSIONE

I SESSION

GEOLOGIA - PALEONTOLOGIA

GEOLOGY - PALAENTOLOGY

Chairman: F. ZARLENGA

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Geological World Heritage: GEOSITES - a global comparative site inventory to enable prioritisation for conservation

Il Patrimonio Geologico Mondiale: GEOSITES - un inventario comparativo globale dei siti per permettere la scelta delle priorità per la conservazione

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ABSTRACT - GEOSITES is a new and ambitious scheme to promote geoconservation. Earlier attempts at selecting geological sites for World Heritage status have come up against the problem that there was no international listing, let alone a fully documented global inventory or database of key Earth-science sites. IUGS initiated GEOSITES (replacing GILGES) to introduce a geological input to global conservation efforts. To realise the ambition of geologists to have a representative selection of internationally significant sites and terrains included in any World or Regional listing or category of site designation, including the World Heritage List, geologists (including geomorphologists and other specialists) themselves must first undertake the task of compiling comparative national and regional inventories, and this is the purpose of GEOSITES, an IUGS/UNESCO joint project: the task to be performed under the guidance of the Global Geosites Working Group (GGWG). The former Global Indicative List of Geological Sites (GILGES) project (under IUGS, UNESCO, IGCP and IUCN) was a first attempt to select prospective sites for World Heritage status, but this revealed the gaps in knowledge and clearly demonstrated those regions and countries where information was lacking. It also revealed that a far larger project was needed to assess global geological world heritage. This task may be a daunting one, and it will certainly take some years to achieve if all relevant individuals and organisations are consulted and all key sites assessed.

To make any sense of the complex geomorphological, stratigraphic, volcanic and tectonic pattern of any country or region a concerted effort is needed, firstly to define the context, and then to fit sites (compared and graded) into that context. The former GILGES project suffered from the fact that there are inherent problems in trying to assess single sites in isolation as unrelated *ad hoc* suggestions: GEOSITES therefore is different - it is an inventory of single sites (or complexes or terrains of sites), but its methods are founded on the compilation of 'nested' national groups of localities, justified comparatively in a defined regional geological context.

All are asked to make their contribution to the work of the Global Geosites Working Group - either individually or collectively - to join one of the regional groups being set up, and to help in the proposal and documentation of geological heritage sites from their country.

KEY WORDS: nature conservation, geoconservation, GEOSITES, global inventory, IUGS, World Heritage.

RIASSUNTO - GEOSITES è un progetto nuovo ed ambizioso per promuovere la geoconservazione. I primi tentativi di selezionare i siti geologici per lo stato del Patrimonio Mondiale si sono scontrati con il problema dell'assenza di una lista internazionale e della mancata realizzazione di un inventario globale o di un database dei siti-chiave per la Geologia. Lo IUGS ha iniziato GEOSITES (che sostituisce GILGES) per introdurre un input da parte dei geologi verso gli sforzi globali per la conservazione. Per realizzare l'ambizione dei geologi di avere una selezione rappresentativa di siti e terreni di rilevanza internazionale sempre inclusi in qualunque elenco Regionale o Mondiale o nella categoria di

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designazione dei siti, gli stessi geologi (inclusi i geomorfologi ed altri specialisti) devono prima affrontare la compilazione di elenchi comparativi regionali e nazionali, e questo è lo scopo di GEOSITES, un progetto congiunto IUGS/UNESCO: il compito deve essere affrontato sotto la direzione del Gruppo di Lavoro Globale dei Geotopi (GGWC). Il precedente progetto Lista Indicativa Globale dei Siti Geologici (GILGES), (a cura di IUGS, UNESCO, IGCP e IUCN) è stato un primo tentativo di selezionare eventuali siti per lo stato del Patrimonio Mondiale, ma ha rivelato i vuoti nelle conoscenze ed ha chiaramente evidenziato quelle regioni e quei paesi in cui l'informazione era carente. Esso ha anche fatto emergere che era necessario un progetto di gran lunga più vasto per valutare il patrimonio geologico mondiale. Questo compito può sembrare scoraggiante, e ci vorranno sicuramente alcuni anni per realizzarlo se verranno consultati tutti i principali studiosi e le maggiori organizzazioni e verranno esaminati tutti i siti chiave.
Per dare un significato compiuto al complesso profilo geomorfologico, stratigrafico, vulcanico e tettonico di qualunque paese o regione è necessario uno sforzo coordinato, prima di tutto per definire il contesto, e poi per adattare i siti (confrontati e valutati) a quel contesto. Il precedente progetto GILGES ha sofferto i problemi intrinseci di valutazione per singoli siti isolati come suggerimenti scorrelati *ad hoc*. GEOSITES perciò è diverso – è un inventario di singoli siti (o complessi di terreni o siti), ma i suoi metodi sono basati sulla compilazione di gruppi nazionali di località «ciclici», giustificati comparativamente in un contesto geologico regionale definito.
Viene richiesto a tutti di dare il proprio contributo al lavoro del GGWC - sia individualmente che collettivamente – di aderire ad uno dei gruppi regionale che vengono costituiti, e a collaborare nella proposta e nella documentazione dei siti per il patrimonio geologico del proprio paese.

PAROLE CHIAVE: Conservazione della natura, geoconservazione, geositi, catalogo generale, IUGS, patrimonio del mondo.

1. – INTRODUCTION

Geosites is a global project, initiated by IUGS, and now also under the auspices of UNESCO, which has as its aim the production of an evolving, systematically compiled inventory (and database) of the most valuable sites for geology (geotopes in German-speaking countries). Such a project has potential usefulness for education and research: it certainly has potential for the promotion of a greater knowledge of geology amongst a wider public. Any such global inventory has significance for wider initiatives in geoconservation, and, in particular, for schemes to define broader designations of site, and it invites cross-border links and collaboration. It should form a natural support for, and enable, consideration of candidate sites for World Heritage in the future, for it fills a large gap in knowledge which has long been apparent. In the past, the few geological sites which have been proposed for World Heritage status have had to be judged for the most part in isolation, with little or no comparative data, and certainly no database of related sites which would allow consideration of the regional, let alone global, setting.

Broadly, the aims of Geosites are to compile the global Geosite inventory of key sites and terrains and comparative assessments of sites, to assemble the Geosites IUGS database, to use the Geosites inventory to further the cause of geological conservation and thus support geological science, aiding regional or national initiatives to compile comparative inventories. To achieve these ends requires participation in, and support for, meetings and workshops that examine site selection criteria, selection methods or conservation of key sites. This is a geological community activity which is already involving specialists, research groups, associations, commissions, subcommissions, etc. Ultimately, it will be possible to advise IUGS on the priorities for conservation in the global context, including World Heritage candidate sites. Without such a global inventory, and allied comparative assessments, attempts at designation of global sites would be open to the criticism of being subjective, based on incomplete data, and, through being unrepresentative of the global picture, of being unbalanced and unfair.

Geological conservation is well established and thriving in some countries, but even so geologists often state that geology is the poor relation in conservation, and this has certainly been said in discussions of the World Heritage List in relation to its lack of geological sites. Geosites presents an opportunity to make a significant step forward in the identification and conservation of the geological heritage. Practical action towards protection of sites has always, of necessity, had to follow an assessment of the resource and identification of core areas: this is as true globally as it is locally or nationally. With an inventory that aspires to be objectively compiled and reasonably comprehensive, this would be a logical prerequisite before global decisions on geoconservation.

Many Earth scientists contribute to conservation day to day, and many of us are involved in saving sites from damage and destruction. Philosophy and winning the hearts of a wider public have preoccupied some in recent years: it has even been stated that discussion of selection and practical conservation methods are lower priorities and that site inventories should not be a main focus for activity. We believe otherwise, that geoconservation without site conservation (justification, selection, protection, management, including publicity and public involvement, etc) is completely meaningless and pointless. The wonder and the importance of the geological record (for geologists and all others) lies and is demonstrated in sites.

That irreplaceable geological heritage is the foundation of our science and of all knowledge of the Earth's past: geology is also the 'backdrop' and foundation for biological/ecological science, and the dominant element in most landscapes. Geodiversity is the basis of biodiversity. However, for much of the world the resource is still not fully assessed. Here, in the Geosites project, is a chance for all to do something constructive, for the geological community to make a tangible contribution to the conservation of World geological heritage, and perhaps to strengthen national capacity to conserve. Only geologists and geomorphologists can make this contribution, on behalf of their science and of the sites on which we all focus our educational and research activities.

2. – APPROACHES TO SITE SELECTION

Geology, in its traditional sense (including geology, geomorphology and all elements alternatively referred to as the Earth sciences), is the study of the exterior and interior of the Earth: clearly many phenomena are potentially globally distributed. One can meet, for instance, Proterozoic, Silurian, Devonian or Pleistocene strata in many parts of the globe, as one can find evidence of past ice ages or riverine environments or soil formation. Geological processes are at work now as they were in the past. Landforms often provide continuity, in terms of processes, between the distant and recent past and the present.

How to assess geological World heritage in a meaningful way: that is the big question. Clearly there would be no sense or merit in wishing to identify a few of the most obvious and well trodden localities - panoramic landscapes, ones relating to the evolution of man, or others supposedly with popular appeal, such as dinosaur sites. The Earth is four and half thousand million years old. How do we demonstrate and weigh what is valuable in the portion of history that survives in the rock record? How do we demonstrate continental growth, migration, collision and destruction, the evolution of life, of sedimentary basins, of mountain chains, rifts and volcanic provinces, *et cetera, et cetera,* as well as examples of geological processes which are still in progress, such as volcanicity or glaciation or coastal processes?

To choose only one of these, to demonstrate organic evolution over a period of 3,500 million years, in even a sketchy and superficial way, would require not a handful, but many localities. Many would be required to show the vital links, lineages, extinctions and appearances, abundant representative fossil assemblages and their environmental or sedimentary settings. We use fossils only as an example: neither this nor any other special geological interest should be viewed in isolation outside the context of its overall geological, stratigraphic/palaeoenvironmental, landscape or regional setting or framework.

2.1. – Methods

The same classifications of rocks and landforms, of minerals and fossils, and divisions of geological time apertain worldwide. It should therefore be possible to take the first hurdle, that of basic geological categorisation, fairly easily. It has been done numerous times and is the bread and butter of national schemes for selection. So types of site are a simple matter and not too much of a distraction. (That said, certain questions, concerning scale, regional contexts, grouping of categories and database structure need to be considered. Addressing these issues, linking them to selection criteria, will contribute to a sound and strong system, both scientifically and with regard to practical operations).

The next hurdles are the identification, suggestion and selection of potential sites for the international listing. The scale of this undertaking immediately requires that a systematic method be employed, including integrated inputs from national and supranational groups of contributors.

How nations contribute is for them to decide. A good approach, already adopted by some, is to form a committee or liaison network, to organise national support which is as broad as possible. Although decisions will be made in each country on a final list of proposals, each suggested site will need to be vetted by groupings of geoscientists and others working in concert in the region, so cooperation between countries is a key part of the process. That said, inventories do not exist for all countries, and some countries have yet to compile theirs. In other countries such an end-product is a long way off and a national selection must be achieved so as to contribute to Geosites.

2.2. – Selection In The Countries

Statute and legal protection are not the concern of this paper. It is anticipated that most suggested geosites have or will be afforded protection in due course if they are to be listed (see Appendix 2 and 3). There is the possibility that Geosites selection will trigger the protection of a site for the first time in a country. It is sufficient to say that laws and protection vary greatly between states - from those with full recognition of small and large 'sites' of geoscience interest to those with no focused law or geoconservation activity. In between, there are countries who achieve recognition of some sites through planning law or mechanism, mineral planning or resource law or primarily historical or cultural statutes. Many countries have state or county listings: some few previously suggested geological sites for World Heritage status through the short-lived GILGES project. However, there do not exist ready-made listings which can simply be 'nested' one in another to build up a global inventory.

It might be informative to look at some methods employed in the past within countries, as a preliminary to consideration of this wider task of forming an international inventory.

The quota method is one approach. It was once suggested, not so long ago, in Britain that geology should be represented in the list of Sites of Special Scientific Interest by a quota of localities (5) per county (!). This method has little to recommend it in demonstrating a natural and comprehensive system, as it is arbitrary and involves the dismissal of most potential sites.

One widespread method has been to select monuments, smallish sites for spectacular or unusual interests: sometimes these may have historical or folkloric significance also, such as caves, springs, arches, boulders, rock and earth pinnacles. Some countries have assayed their entire geological resource and at least listed those localities of special scientific interest: such are in the minority. Some few have on-site interpretation in profusion (e.g. USA, Sweden), and others have produced excellent guides promoting a dual scientific and conservation message (e.g. GRAVESEN, 1996; LARSEN & KRONBERG, 1992). In a number of states, larger areas have been designated: often this is on the basis of mixed reasoning - for instance, reserves, national parks and the like have been selected as wildlife refuges or wilderness areas, frequently with some geological justification used in support of wilderness or biological considerations. Geology has thus been used as an adjunct to other interests, even though the dominant element in the landscape may have been the geological one. Such larger areas may have been selected for designation for amenity or to control usage, thus furthering management of the countryside or wilderness tourism. This is not to say that tourism is not a valid criterion for setting up certain categories of site, but here our concern is specifically that which is geologically outstanding. So, in some countries, Reserves and National Parks frequently have interesting geological phenomena, but this special interest, deserving prominence, protection and interpretation in its own right, is often subordinated or overlooked. And, even if this is not the case, a few reserves, even if geologically focussed, demonstrate the diversity of an entire country.

Thus there may be states or parts of states where a few sites are the focus of attention for conservation: sites demonstrating a fuller geological history for the country have not yet been a paramount concern and, therefore, geoscience is under-represented or at least lacks overt recognition. Another consequence of this skewing of sites is that financial resources are channelled into a small number of localities which are intensively managed.

Countries, if they undertake comprehensive surveys of the geological resources, may select sites in a national or subnational setting. Very few sites are actually selected to represent portions of an international pattern, time period, event or topic. Some countries only select sites by smaller subnational administrative areas (counties, cantons, departments, parishes, communities, etc.) rather than by broader geologically derived topics. It is difficult to assess sites in a regional or international setting if their original selection was based on more locally derived parameters.

Few states have consciously and explicitly selected a significant number of large terrains specifically for their outstanding geomorphology or geology.

If one combines these various factors, there are some obvious problems:

– interally, full recognition may not be given to geological sites and terrains of national/international significance;

– local, national, and sometimes international, themes may have dictated the compilation of a national listing;

– a lack of full, balanced national lists makes international comparisons and designations difficult.

Therefore, international commitments and responsibilities to protect superlative portions of the global geological heritage are often not currently fulfilled at the national level.

However, it is important to note that if we can collectively, as an international geological community, produce a list for each nation and have the sites in that list recognised internationally by a process of peer review, this may help nationals to improve the status of geology and geoconservation in their country.

3. – APPROACHES TO A GEOSITES METHODOLOGY: OBJECTIVES

If we presume that national inventories in some form are a possibility for all countries, how should we approach selection of a global listing?

In conservation there are limited resources to hand, and we seek to place them where they will achieve the greatest good. This means determining the relative value of sites and areas, and putting effort into designating and protecting those that really matter, avoiding misplaced efforts on others: those working on Geosites wish to follow this logic.

We have therefore to select a limited, but representative, set of sites, to produce a balanced coverage between countries and regions. That group of sites has to represent all significant processes and salient events, time periods, features and topics: however assessment needs to be undertaken on a scale and with sites grouped in such a way that it is practical, and which will allow an overview of the system. Geology and landscapes do not respect national borders: therefore coverage of sites and terrains has to conform to regional patterns.

3.1. – Alternatives

Let us examine some methods of selecting sites. What might be the possibilities?

i. Select in an *ad hoc* manner, that is, choose single sites in isolation.

ii. Concentrate on certain types of site, judging them to be the most important kinds.

iii. Select sites/areas that already have some conservation label or designation.

iv. Choose some token sites, without a full survey, that is, a few superlative localities.

v. Define a context and select within this context.

Any of these methods can be made to work. But, for the reasons discussed here below, we regard options i-iv as imperfect ones, and do not see them as realistic, comprehensive or reasonable propositions.

Nevertheless, we discuss them for completeness and balance. Methods ii-iv may have some usefulness and more validity if employed within the framework of a systematic scheme of selection of course.

i. *Ad hoc method*

Some might advocate a laissez faire approach, whereby each country suggests sites in isolation in an *ad hoc* way, each a site of merit viewed from an internally focused national (or even subnational) perspective. This can undoubtedly work where individual superlative localities are involved: the 'right' choices can often be made. However, the problem is one of consistency, and such a method might lead equally to local preoccupations overriding consideration of broader patterns and significance. Just as when small monuments are selected within a country, there are inherent problems connected with a skewing of the selection process towards the unusual; the oddities one might call them. The smaller the area of search the more 'special' appears the feature or site being assessed (Wimbledon *et alii*, 1995). The speculative locality can never fail to appeal as a choice, if similar sites in other areas go unassessed.

Such an *ad hoc* method also gives no contextual framework for judgement of regionally or globally significant sites: with no relativity, there is little scope for comparison and thus scant possibility for assessment of true significance. Single suggestions of sites may allow scope for local and national assessment, although even there it would be an imperfect assessment. Single suggestions also allow the possibility that other factors will be brought into play - political, cultural and physical management, for instance: all of these have their place, but they are factors which may work to the detriment of consideration of regional or global scientific significance.

Ad hoc approaches therefore would have limited merit, if attempting an investigative and truly comprehensive survey. The problem is that key events in the history of the Earth and life are many and complex and not all are even clearly discernible in the geological record. The *ad hoc* method, incidentally, was the method previously employed in attempts at selecting World Heritage sites, in the sense that all previous suggestions have had to be viewed in isolation, and not as part of any internally comparable plexus of like localities or areas.

It can be seen from comments already made that anything less than a reasonably exhaustive survey gives a fairly random product, because too much is left to chance.

ii. *Decide some categories or types of site are more important than others*

Such an approach would involve dividing up geology, avoiding a meaningful consideration of the matrices of time, stratigraphy or tectonics. It requires an *a priori* judgement that certain kinds of sites should be included in preference to others; thus separating a category from the mass and selecting localities in that category in isolation. It might be suggested that attention should be focused upon spectacular sites (for minerals or fossils, or sites related to Man, or vertebrate sites, or meteor impacts), to the exclusion of other, perhaps less obvious, but outstanding, localities. An instinctive and almost instantaneous response from many geologists to such a suggestion would be that the organic evolution of the Earth is intimately bound up with the Earth's inorganic/physical (chemical, sedimentary, igneous and tectonic) history, and that this makes piecemeal categorisation look rather an unnatural process.

Such a method is subjective, and it ignores the interest and value of all inanimate and animate features in the geological record, the complex mosaic of interrelated interests which make up geology, and the enormity of geological time. This last factor is critical, for when dealing with periods with lengths of sixty or one hundred million years, and epochs of ten or twenty million, it is no simple or obvious matter to choose five or ten or even fifty token sites to represent a given time interval!

A priori judgements that certain pre-selected categories are important, as opposed to a fuller range, go against a natural approach and drive the selector towards imposing quotas, as well as jumping to conclusions about some categories being more significant than others. Are fish fossils more interesting or important than metal ores, are sulphides more interesting than hominid fossils, is a beach more interesting than a profile though fossiliferous Silurian strata? The answer is, of course, that they are simply different, they are not directly comparable: spatially they may even overlap one another, and often do, and they are all parts of the rich and varied record of the Earth. The natural interlinking of many aspects of geology and physical interests, such as environments, stratigraphy, fossils, sedimentation and minerals, makes their inseparability an important issue. (An *a priori* system may be, and is often, used as a practical strategy, within a framework of political necessity. That is not implying that parts of geology are more important than others, but that a political system can accept responsibility for amending purely scientific judgements on the basis of practical need, such as immediate threat. This is however difficult to apply in an international/worldwide setting.

A variant of the categorisation approach is the one founded on selecting the 'best', the 'first', 'oldest' etc: a subjective 'high-grading' process. The idea of compiling such a 'top 10' lies outside the realm of objective scientific assessment and is not appealing for that reason. No matter how good a locality may be, it cannot, singly or with a few other 'chart topper's, demonstrate the full range of features for a particular interest or area.

If one categorises geology, and overlooks the thematic and time connections which unite sites (eg. time correlation, common paragenesis, tectonic or metamorphic history), selection becomes much more subjective and slanted, one might say distorted. There is a tendency to select the more obvious, to select the 'plums', and sometimes to select similar sites in different areas, while overlooking other categories. (On the other hand (see V below) we must not get swamped in the detail, blinded by the diversity of nature. Categorisation and regional context definition save us from this pitfall).

Also, not forgetting that national sensitivities are involved here, this method would not give a fair coverage of localities between the countries; if the categories are the wrong ones, and this is inevitable if broader patterns are not assessed, some countries would finish by having no sites in the list. It would be difficult to promote anything that was not an objective or equitable survey.

iii. *Select sites/areas that already have a conservation label or designation*

Another approach might be to select a global list on the basis of pre-existing designations. It might be suggested that all sites/areas should be drawn from already determined designations, for example, reserves or special sites or parks. Of course, whatever the individual merits of special areas within such categories, there is no getting away from the fact that a few parks or reserves cannot represent very much of a country's geological history or geodiversity. There is no firm conviction that each category has been founded on a focused assessment of geological interest. In addition, to rely on the accidents of various designations or management labels already in existence would leave those countries that have no such designated areas without any input to a global inventory. Finally, it has to be said that any such list based on designated sites could well be drastically skewed and biased towards land management or legal categorisation rather than science or interest, or relative merits.

Stratotypes or other type of standard localities (chronostratigraphic, lithostratigraphic, etc.) might be regarded as another kind of designation. Such type sites exist for many things and careful thought needs to go into comparing their true merits. A mechanistic presumption that labels are directly equivalent to significance is perhaps not sound. This will not be true of key boundary stratotypes (GSSPs: see 2 below) or major historically significant terrains, however, where the task is one of defining areal limits rather than of assessment.

The overriding and conclusive reason for not using this approach would be 1) that all countries do not have geological sites listed, let alone designated or protected in some way, and 2) any designated sites (excluding GSSPs) that do exist were normally not selected as part of a holistic consideration of regional and wider geological settings.

iv. *Choose some sites without a survey, selecting a few superlative localities*

This is an approach that might be termed tokenism, a conceptual approach that is diametrically opposed to selection based on objective survey and representativeness. Conservation in quite a few countries is based on protection of sites identified through the systematic compilation of national inventories. Some of these rely on the establishment of networks of sites selected because they demonstrate particular temporal or thematic interests. Such surveys and assessment processes afford the best chance to select sites which are truly representative of a given area and/or time period. Such country or regional surveys also afford the most useful tools in compiling global inventories and deriving global priorities. Alternative methods have their problems.

Time is, of course, the big factor which separates geology from other disciplines. As stated, its enormity makes tokenism difficult: for in putting together any reasonably complete global listing it would be necessary to have representation not only of processes and features, but also to exemplify these through the whole of geological time, not forgetting to take into account regional variations. This cannot be done with just a handful of sites. If such a small sample of obvious geological sites were selected to supposedly demonstrate the whole of geology and geomorphology, it could justifiably be said that they were unrepresentative, and the surveys and designations associated with them would be discredited.

Keeping with the fossil record as an example, to demonstrate evolution through time potentially involves us in understanding and recognising (even in an imperfect fossil record) the appearance and disappearance of uncounted species, plotting the radiations of all the lineages and taxa that have graced the Earth and then declined to extinction, many of them from groups with no living relatives. The interest of fossils, as seen by the geologist, is their connection with their setting, the environment in which the organisms lived, or in which they died and were buried and fossilised, and the inter-reactions between the organism in life and its substrate, the climate or biota of the time. Rich and sometimes quite peculiar fossil assemblages (*Lagerstätten* in German), for instance, are some of the best known geological sites, and they may be valuable records, but they are often not representative in a wider context. Should we not be looking to show significant parts of the record, telling a broader story, but still noting important appearances, and extinction events, evidence of key catastrophic happenings that affected life (e.g. glacial or anoxic events), and plotting these in the time continuum? A good example of the challenge is afforded by major extinction events in the Phanerozoic. Some nineteen large-scale events have been recorded, counting those with more than 50% species loss. Each of these is recorded at more than one 'site' and with varying degrees of clarity and precision. It is clear that some work is needed to decide which site best represents each event, if that is possible, but first it has to be decided which events need to be demonstrated.

It is fine to say let us select one, or two, or five sites to demonstrate the Jurassic System. What do we demonstrate? Organic evolution, faunas or environments (not to mention sedimentation, basin development, plate tectonics and sea-level change)? However, it is not that simple, for one has to consider the notion of geo- and palaeobiodiversity. That period had a broadly distinctive, but changing, fauna and flora, reflecting in part climatic and topographic change, and fluctuating sea levels. The Jurassic in Greenland and the Pacific, or the type localities of W Europe and the USA, for instance, despite the time label they bear, in detail have little in common and are often correlated with difficulty. The period was 75 million years long, and species at its beginning were very different to those at its end, or its middle, or in its several parts. Man's time on Earth has been but the blink of an eye by comparison. To demonstrate one fossil group's development or the development of one kind of environment through this or any period would alone require a significant number of localities. Even sites like Solenhofen, Holzmaden, Stonesfield or Como Bluff (all included in the Geosites inventory, and superlative localities! - see fig.1 also) show only a fraction of what is special or typical in the Jurassic. Some of them could be said to demonstrate peculiar or abnormal environments, rather than typical, representative or widespread ones. No small, token, number of sites can adequately demonstrate any given geological period or theme.

v. *A method based on systematic survey and comparative assessment*

From the above it can be seen that methods (i-iv) are not the ones preferred by the Authors: they lack scientific rigour, and fall far short of a systematic, balanced and fair ideal. A survey based on national and regional assessments is our preferred method.

4. – THE COMPARATIVE METHOD

How should the task be performed following method (v)? Firstly, in one matter we have no choice: we must recognise the scale of the geological resource, and the potential interests available. This gives an indication of the potential for selection and the numbers of sites involved, based on various natural classifications of geological themes, regions and time.

If geological history had been the same in all parts of the world, and if the environments, rocks, fossils and minerals had been of uniform distribution, then the task would have been a simpler one. A lesser number of sites might have sufficed to demonstrate global patterns. However, this is far from being the case. Evidence of the Cambrian or the Jurassic periods, or of Carboniferous floras, or Cenozoic mammals, or of the Variscan orogeny or metallogenesis is not represented in the same way or uniformly throughout the world. Sedimentation, biotas and ecosystems were never uniform, nor were volcanism or mineralisation. Therefore, the challenge is to select and document, not token examples, but those features, sites and areas which show broader patterns, which allow comparisons and correlations, and give an in-depth understanding of the Earth's evolutionary story. Clearly there is no scope or intention to represent every part of each regional or national pattern: the superlative nature of the site will ultimately determine selection, and some sites will fit no pattern, except a time frame.

The scale of this story is a continuing source of wonderment to us Earth scientists and, always, to a lay public: to choose sites which encourage and foster such wonder and awe is also part of the challenge we face. From that awe and a respect for sites comes an understanding and appreciation of the need for conservation. It should not be forgotten that outstanding attributes that allow or indeed demand educational and interpretational use are another dimension to sites, still founded on scientific interest and understanding, but of significance in their own right. So, there is an opportunity to include sites of the highest value for educational and inspirational purposes.

In any compilation of a global inventory, certain kinds of site need to be included. These should show significant stages, the special and, especially, the representative. It is clear that Geosites cannot include all the vital stages of the fossil or the inanimate record of every period, epoch or stage, although the ambition is to encompass many of them.

4.1. – Representativeness

It has become more and more clear in recent times how important in national site selection programmes is the criterion of representativeness. Meaning not having sites to represent all that is commonplace, but sites demonstrating themes and features judged to be of importance in a country or region. Above all others, this vital element was recognised in the former GILGES project as essential. (Cowie, 1993: see also, for instance, Wimbledon *et alii*, 1995). It is clear that in any context, local, through national to international, representativeness is the criterion which is most important in site selection and justification, and the construction of complementary networks of sites.

Geosites has adopted as its starting point just such a methodology, selecting sites in a comparative and thematic way, comparing sites' interests and their merits in a defined context or pattern (Zagorchev, *in press*). This in no way detracts from the value of demonstration/didactic sites that might be included, but it gives the conviction that all matters, visually impressive and otherwise, are being systematically assayed.

4.2. – Geosite Mechanism

Understanding the geological record and its salient and important features requires the assistance of workers in many fields. Geosites in practice relies on contributions of site suggestions from country committees, national agencies and individuals. The aim is to channel such suggestions of single localities through regional working groups, each group endeavouring to place a locality within a time, rock or other setting. Such regional groups will be able to call on the advice of other specialists, including, for instance, IUGS sub-commissions.

The inevitable corollary to the broader comparative approach, taking full cognisance of geological time and diversity, is that compilation of a definitive inventory for Geosites, if done properly, is a large task which will take some years to complete. Colleagues already involved in Europe have estimated that there it will take at least three years' work to set down criteria, more particularly to define regional frameworks and to achieve a preliminary listing.

Who will do the day-to-day work of Geosites? Geosites, to be successful, will work through national contributors, who will put together a coverage of localities or areas which demonstrate the salient features of terrains, epochs and topics, showing what these have that is typical, special and representative (see Appendix 1). This is a much larger undertaking than any previously considered. National Committees for geology have already been contacted by IUGS, and their support enlisted.

To make a professional job of it, inputs must be invited from all with an interest in the sites. Much work will be required to put together a fully justified network of localities, following up with the documentation for each suggested site. There is no 'quick fix' that will allow the instantaneous definition of any kind of geological site, let alone larger inventories. Therefore, objective selection will take time: if short cuts were to be used, the product could only be a hurriedly compiled, subjective and selective list.

Although regional comparative assessment and validation is important, indeed the key to the process, ultimately all selections will be made by geo(morpho)logists within the countries. A decision has to be made early in the process, that, in site proposals, *ab initio* no central control will be operated - no 'shopping list' decided in advance, and no sites will automatically be included: national and regional groups of workers must be left to propose those sites which they judge represent the geological record of their region. Careful and sensitive comparison, vetting and discussion will involve many at later stages in the work. That is not to say that quality control will not be an important element later in the process. In some instances a country may take responsiblity for assessing a particular interest in its region, for instance when that interest is best represented in that country in the region.

It is being recognised that geology forms terrains, and that geology can be the dominant element in a landscape. Plexuses of sites (let us call them nodes or locuses) may be scattered across a landscape, numerous locuses of varying interest and importance making up a terrain, and all sites adding to our knowledge of a time interval or area. This is not news to geologists, because mapping, a fundamental activity central to the science, has been going on since the end of the 18th century. In the conservation context, it has significance because it is the complex of inter-related sites which provide the total database for geological science, and thus the total resource for conservation. Thus the plexus carries conservation value, and not just the outstanding sites (locuses/nodes): many sites may be complementary parts of an interest. Geodiversity is just as much a fact as biodiversity. Recent development in Europe of a strategy that recognises the place of geology at the heart of landscape is most encouraging (PAN EUROPEAN BIOLOGICAL AND LANDSCAPE STRATEGY, 1995)

Because of this natural distribution of 'interest' in geological terrains or landscapes, it is necessary to consider groups of complementary sites and not just the most obviously superlative ones. Geosites can accommodate sites ranging from those of high sub-national value, through national and regional, to those of the highest international significance. It can include terrains or site complexes (with numerous locuses) or, at the other extreme, "minisites" (small-scale localities with concentrated high-levels of interest), to steal a term recently coined by botanists.

So, to reiterate, the method is to assess in a matrix of comparative and contextual layers.

The starting point might be the geological province or structural framework unit, say the Caledonides of NW Europe or the Pannonian Basin of SE Europe. Then assessment might be of the type of site (Appendix 2), or a process. For instance, the mineral/metallogenesis localities of Sardinia or Cornwall would be assessed in the setting of pre-Permian terrains, perhaps with granitisation and late-stage metasomatism. Site assessment is in the frame of Variscan Massifs and processes and sequences of late and post-Variscan intrusion and mineralisation; species of minerals might also be considered. A third level of assessment might be the site's completeness of record (see Appendix 1). Then other, practical, considerations come into play, such as condition or protection or access, or lack of it. All these lines of evidence need some assessment and have, to a greater or lesser extent, a part in the overall rating of a locality or area. Appendices 1 and 2 give more guidance.

We use some examples herein to demonstrate, in outline only, possible frameworks for site selection. The exemplars are far from exhaustive, but show how broad a range of sites a time-based or topic-based approach could generate.

4.3. - Early Application Of Geosites Technique

In Europe, a number of national groups and individuals have already started to take up the Geosites challenge, and this work is acting as a pilot for Geosites in a global setting. ProGEO is acting as an agent for IUGS in compiling a European inventory, and its regional working groups are contributing to sub-European listings. ProGEO has started to use the comparative and regional approach advocated for the project generally. Europe, as a geological entity, is being considered under its natural subdivisions - the Precambrian shield, the Caledonian orogen, the Variscide front, the Variscan massifs, the Alpine fold belts and so on, following the classifications of Stille (1924), Ager (1980) and others. Within each tectono-geological framework element, stratigraphic, igneous or metallogenic successions or events, for instance, can be considered. Parallel approaches will be undertaken on particular topics or groups, geomorphology, etc. The aim will be to demonstrate the salient element in, for instance, a tectonic setting such as the Variscan Front or a stratigraphic sequence within such a tectonic framework element, for instance a key Tertiary section in the Danish Triangle.

To compile regional inventories, selection will be made within regional geological contexts such as those described in the previous paragraph, placing sites within national and then regional contextual 'shells', like nested Russian dolls. In addition specialist groups will be asked to work in parallel, contributing on particular topics, such as particular mineral groups or tectonic elements or glacial limits. For instance, work has already started on a draft international list of sites recording the salient features of palaeobotanical history, and discussions are going on over a similar vertebrate listing (both in stratigraphic and time contexts). The former list will contain sites demonstrating the most important elements in the evolutionary story of plants, related to environmental and other change. It, like other specialist inputs, will be used to assist national efforts, and as an aid in documenting sites and a guide in making selections. Students of igneous processes and stratigraphy will likewise be co-opted to give inputs on key sites within their purview.

As examples of the approach, below are a table and two figures illustrative of the process of framework or context definition in action. The first shows the key reptile and mammal-yielding sites of the Jurassic and early Cretaceous sites now being assessed for Geosite inclusion (fig. 1). This demonstrates a number of globally significant localities or areas. It shows the distribution of sites through time. Some intervals have no representative, some have only a single site, but in only a few cases are there several sites between which to make comparisons. Where more than one site represents a stage, facies are sometimes very different, marine as opposed to non-marine, with faunal consequences. Selection will be made by comparison of biotas and by assessment of stratigraphic, evolutionary/systematic and environmental settings. Of course these same sites and coeval localities also have to be considered for other faunal and floral elements as well as for palaeoecology, not to mention sedimentary and stratigraphic considerations.

Figure 1 is a first attempt at assessing a stratigraphic interval, the Precambrian-Cambrian boundary and the Cambrian System. In this late Proterozoic to Phanerozoic interval the succession of various biotas can be charted, showing the transition from sparse soft-bodied faunas to abundant life forms of the Cambrian - a transition which has received intense stratigraphic study in recent years. These faunas have a dominant role on the stratigraphy of this interval. Figure 2 shows the Geosites (numbers in columns) already proposed for this Precambrian-Cambrian transition, charting vital stages and stratigraphic sequences, specific biotas and bio-events.

Below is a preliminary listing of sites illustrative of floral evolution in the Palaeozoic (tab. 1). This is presented with no documentation, which will be published elsewhere to generate a full debate of the list, but it gives some idea of the scale of the undertaking and the database that exists: the sites proposed derive from a first assessment of the resource and early discussions amongst palaeobotanists. If nothing else, the list gives some idea of the number of sites regarded as being essential to show only one element of evolution, mostly higher plants, in only one era. Here are a whole suite of localities of world renown.

5. - CONCLUSION

Geosites is gaining momentum as a project; it offers prospects for collaboration, and for strengthening efforts in both national and international conservation settings: lending support and helping to further national, internal initiatives and giving geologists regionally a focus for common efforts. It gives IUGS the possibility of assembling a database and organic liaison network which it can use to advise on global conservation priorities.

	Britain	Europe	Nord America	Other continents
Aptian				
Barremian	Clock House; Brighstone	Bernissart Nehden Galve	Lakota	Santana
Hauterivian	Brighstone			
Valanginian	Hastings, Telham			
Berriasian	Duriston Bay; Isle of Portland			
Tithonian: Portlandian	Chicksgrove; Isle of Portland	Wimereux, Wimille	Morrison	
Tithonian: Kimmeridgian	Kimmeridge Smallmouth; Isle of Portland	Boulogne Solenhofen, Eichstätt, Cerin,Guimarota	Morrison	Tendaguru
Oxfordian	Peterborough			Shangshaximiao
Callovian		Dives		
Bathonian	Shipton, Kirltigton Stonesfield New Park	Caen		Xiashaximiao
Bajocian				
Aalenian				
Toarcian	Whilby	Holzmaden	Navajo	Khota
Pliensbachian			Kayenta	
Sinemuriam				
Hettangian	Lyme Mendips/Bridgend		Wingate Moenave	

Figure 1. – A correlation of Jurassic and early Cretaceous reptile and mammal-yielding sites as against a standard stage chronostratigraphy. Sites which merit assessment as Geosites.

– Una correlazione dei siti del Giurassico e dell'inizio del Cretaceo contenenti rettili e mammiferi rispetto ad una cronostratigrafia standard degli strati. Siti che meritano una verifica come Geositi.

It would be logical to base World Heritage considerations on a fuller survey such as Geosites, to allow comparative judgements to be made: geologists want to see a representative coverage of geo(morpho)logical sites in the World List, although others have suggested the need for new categories to accommodate globally significant geology (eg. ALEXANDROWICZ & WIMBLEDON, 1995). If there is a ceiling on geological site numbers in the World Heritage list, then it is obvious that sites sufficient to show the diversity of geology over time can never be accommodated: it is a problem of numbers, what is called, in old-fashioned (non-metric) English, "'trying to get a quart into a pint pot". The question posed is - can World Heritage Sites

	Age My	CANADA (Newf'dl'd)	RUSSIA & KAZAKHSTAN	CHINA	AUSTRALIA	AMERICAS	Zones	Major bioevents
ORD.	500	1 st Series	Olentian	Yichangian	Datsonian	Ibexian	Cordylodus spp.	■Tp/Jb
UPPER CAMBRIAN		not named here	80	Fengshanian	Paytonian	Trembea-leanian (Croixian)	Various	
			Shidertinian	Changashanian	'Pre-Pantonian'	Franconian (Croixian)		
					'Post-Idamean'		Irvingella	■Dr/F
					Idamean	Dresbachian (Croixian)	G. reticulatus	■Mi/Id
	510		Tuorian	Gushanian	Mindyallan		G. stolidotus	
MIDDLE CAMBRIAN			Mayan	Zhangxian	Boomerangian	173	L. laevigata	
					Undillan		P. ptretiosus	
							P. atavus	
			77	Xuzhuangian	Floran		T. gibbus	
			Amgan	Maozhuangian	Templetonian	Albertian		
	520		Toyonian	Longwang-miaoan	Ordian	200	229 234	■To/Am
LOWER CAMBRIAN			88 Botomian	Canglangpuar	'Lower Cambrian'	Waucoban		■MBo
	525	Brigus	79 Atdabanian	Qiongzhusian			Various	■4
	530	Bonavista	315 Tommotian 78	Meishucunian III 172		300		■3
	535	Random	Nemakt-Daldynian/ Manykayan 315	II Meishucunian I 289				■2
	545	Chapel Island 282					Phycodes pedum	■1
PRECAMBRIAN	550	Rencontre 313 246	Vendian 315	76 Sinian	Ediacaran	313 203 215		
		108		92	258	196		

Figure 2. – A correlation of beds in key areas at the Precambrain-Cambrian boundary and in the Cambrian System, showing early selected Geosites representing the late Proterozoic to Phanerozoic interval.

– Una correlazione degli strati nelle zone chiave al limite Precambriano-Cambriano e nel Sistema Cambriano, che mostra i Geositi selezionati inizialmente e rappresentanti l'intervallo dal tardo Proterozoico al Fanerozoico.

Table 1: A provisional world list of Geosites for Palaeozoic palaeobotany

Silurian	Tipperary, Ireland Walhalla, Victoria, Australia
Devonian	Clee Hills, Great Britain Craig-y-fro and Llanover Quarries, Great Britain Rhynie, Great Britain Gaspé, Canada Elberfield, Germany Catskill Mountains, USA Bear Island, Arctic
Lower Carboniferous	Southern Allegheny Mountains, Virginia, USA Horton Bluffs, Canada Berwickshire and East Lothian, Great Britain Montagne Noire, France Pettycur, Great Britain Kilpatrick Hills, Great Britain Huadong, China Minusa Basin, Russia
Upper Carboniferous	Washington County, Arkansas, USA Meuse Valley, Belgium Glynneath-Ammanford, UK Guardo Coalfield, Spain Sabero Coalfield, Spain Grand'Croix, France New River Gorge, West Virginia, USA Joggins Cliffs, Canada Point Aconi, Canada Mazon Creek, Illinois, USA Rock Island, Illinois, USA Steubenville road cutting, Ohio, USA Hamilton Limestone Quarries, Kansas, USA Northern Utah, USA Southern Kuznetsk Basin, Russia Rio Blanco, Argentina
Permian	Saar-Nahe, Rotliegend, Germany Kupferschiefer, Central Germany Taiyuan, China North-central Texas, USA Hermit Trail, Arizona, USA Pechora, Russia Northern Karoo Basin, South Africa Skaar Ridge, Antarctica

ever include a full coverage of sites showing the vital stages in the Earth's 4,500 million year history? To 'squeeze' a token geological complement into a quota requires judgements which are of a kind other than geological/scientific.

That said, Geosites has a quite separate identity, validity and momentum of its own. To encourage geo(morpho)logists around the world to contribute to Geosites, we have to convince them that rigorous and methodical approaches are being used, and that data contributed will be usefully employed. Geosites has the potential to lead to a justified world list, it has the potential for the first time to enable us to make truly validated global selections, and to put geoconservation 'on the map'.

IUGS has contacted all national committees to acquaint them of the start of the Geosites project, and has invited their participation. It is hoped that the framework for activity outlined above is sufficient to encourage activity to begin in earnest. Already many national bodies and individuals are involved. Pilot studies for the project set up in Europe, devising and testing criteria and selection methods, have been running there for some months. Enthusiasm for the work has been expressed in many countries, and contacts have been made in most continents to set up networks of contributors.

If you want to further the aims of IUGS in involving geologists in regional and global efforts towards geoconservation, join in the work of the Global Geosites Working Group.

ACKNOWLEDGEMENTS

We thank the many colleagues who have contributed to the discussion of how to advance the cause of global geoconservation, particularly through the compilation of a global inventory, singling out in particular friends in ProGEO (the European Association for the Conservation of the Geological Heritage). Sincere thanks especially go to FRANCESCO ZARLENGA *and* ANTONIA ARNOLDUS *and all Italian colleagues whose efforts and guidance at the Second International Symposium were an inspiration to us all.*

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APPENDIX 1

1. *Geosites Defined Purposes and Methods*

The purpose of Geosites is to identify sites which are of sufficient universal outstanding value to be incorporated in a geo (morpho)logical inventory. This list will be computerised (IUGS Trondheim). The inventory will be put at the disposal of IUGS and the geological community, also the World Heritage Committee.

Any site is suitable for inclusion in Geosites, if it can be demonstrated to be a geological or geomorphological site, terrain or landscape of outstanding value, making an indispensable contribution to an understanding of the geological history of a defined country, region or continent, and of broader or global patterns. Geosites is an open-ended project: its inventory may be improved by deletions as well as additions - it is truly iterative in its nature. Imbalances in the former GILGES listing, both geographic and by geological subject, will be corrected. These imbalances were due to the nature of the responses to requests for information from the countries of the world and sections of the geological community: these highlight the need for full involvement of all interested parties and a focus for future efforts.

It is essential to avoid 'pigeonholing' of sites, forcing data into an agreed (or not) framework instead of allowing the nature of the facts about the sites to dictate the framework which may be later established.

Dialogue and balance between the two approaches is needed.

The geomorphological category has clearly to be covered by the project, but is the most difficult and caused lengthy discussion in the course of the GILGES project. "The role of uniformitarianism in geological thought is very important and studies of present landforms and ongoing geological/geographical processes are vital. This argument could open the door to very numerous site proposals coming forward for deserts, coastal erosion and deposition, river erosion and deposition as well as further suggestions to add to the already large number of proposals for caves, waterfalls, glacial features, escarpments and others. Further study is needed and assembly of comprehensive databases. There seems, however, to be no doubt that geomorphology is a valid and valuable part of geological science" (COWIE , 1993).

Areas demonstrating landscape evolution or containing major stratigraphic sequences were considered somewhat problematic in GILGES, but can happily be dealt with within Geosites and the IUGS database, and the latter category may include global and regional stratotypes and type areas, and larger transects and complex terrains.

Access and availability (see Article 5 of the World Heritage Convention) are a fundamental aspect of both Cultural and Natural Sites. Access to natural sites is vital for scientific study and/or research, and appropriate collection. In the context of Geosites, there should be expectations for future work on the site and in some cases existing management practices may be over-restrictive. A balance must be struck between the desires for conservation and access. Conservation equals preservation, but in the case of geology that includes use.

Geosites Terms of Reference

1. To compile the global Geosite inventory, based on the scientific assessment of key geo(morpho)logical sites.

2. To compile the Geosites IUGS database of key sites and terrains.

3. To use the Geosites inventory to further the cause of geological conservation and support geological science in all its forms.

4. To support regional or national initiatives aiming to compile comparative inventories.

5. To participate in and support meetings and workshops that examine site selection criteria, selection methods or conservation of key sites.

6. To assess the scientific merits of site, in collaboration with specialists, research groups, associations, commissions, subcommissions etc.

7. To advise IUGS and UNESCO on the priorities for conservation in the global context, including World Heritage candidate sites.

Below are guidelines and criteria for the selection of Geosites. They are not unusual, let alone unique, and will be recognised, allowing for variation of terminology, by those familiar with site selection at a national level.

2. *Principles for Assessment of the Scientific Merits of Proposed Sites for Geosites*

A proposer should ask themselves the following questions with regard to a potential candidate site or area.

i. What is the significance for an understanding of geological evolution (inorganic or organic)?

ii. What is its significance for an understanding of geological/geomorphological mechanisms or processes?

iii. How complete are the phenomena present; are all relevant features covered, eg in a volcano how complete is the magmatic series, how many effusive rocks and types or periods of eruption, etc are there?

iv. How well is the object studied, how sizable is its literature, how well are key parameters measures (identification of minerals, fossils, 'absolute'/radiometric age determinations etc)?

v. What is the special, typical or unique feature of the site in time and/or space? How is its rock/deposit/landform and its time or area relationships significant?

vi. What is the quality of the material which is the particular focus of interest at the site?

vii. For what part of the geological column or which geological phenomenon is this site representative?

viii. Categories (stratigraphic, mineralogical, volcanic etc) are not significant in terms of quotes: sites may fall in any category. The types of site a country selects are to be determinated by the nature of its geo(morpho)logical make-up.

ix. Into what selection network (time or thematic) does this locality fall, and make a vital part?

3. *Guidelines for Selection*

Geosites is a global inventory, that has as one of its purposes to act as an indicative list for future conservation initiatives. Justification of the outstanding universal value of a proposed site should be demonstrated: this means that is position nationally and regionally has to be made clear. Its validated place as an example of or part of, for instance, a regional structure, vital stratigraphic internal, tectonic or glacial phase depends on the essential part it plays in elucidating such a theme, structure, event or epoch.

i. Size of an individual site has no significance. Larger areas may contain multiple 'core areas' each independent of 'special' interest: interest, significance and representativeness should be demonstrated for each of these.

ii. Integrity is important, and any site proposed should be conservable and protected from damage.

xiii. Sites with a complex record, subject to multidisciplinary studies or with a long history of research, or a substantial bibliography are likely to be setter candidate sites. But this does not rule out new or unexploited sites.

xiv. Nomination of a Geosite should be in the form of a concise and focused well-argued case. The Geosite documentation form will evolve as the project develops.

In the above itemes 2v, 2vii, 3xi and 3xviii are of paramount importance

iii. Geological conservation principles should apply i.e. conservation means protection for use, including, where appropriate, collecting.

iv. As far as possible inappropriate collecting, by both professionals and amateurs, should be discouraged (except, particularly, in areas of appreciable material loss through natural processes).

v. Sites should not be 'worked out', with all good and representative material removed to remote museums, other collections or private establishments. If specimens are not readily visible then there should be good potential for future collecting.

vi. Museums on site, with collections, may be a satisfactory alternative.

vii. The provision of sites for eduction, recreation, training and research may be a desirable factor.

viii. The integrity and conservation of a proposal should be subject to monitoring, where possible and appropriate.

ix. Geo(morpho)logical sites are best considered singly, each significant interest being assessed: but, synergistically, it may be desirable to group like sites as clusters or within larger entities such as National Parks. However, all sites must be judged individually and be capable of standing alone for the purposes of assessment and justification.

x. Equal concentration of sites by area is not feasible (relative to size of country or other area): this must be the case, to avoid the charge of subjectivity.

xi. In selecting sites for Geosites, it is most important to assess candidates comparatively within a context, to make informed comparisons with other possible candidates: this involves some further research.

xii. Size (the "largest") and age (the "first" or "oldest") are only some of the relevant factors, they cannot be automatically equated with the "best".

APPENDIX 2

Types of Site

1. Stratigraphic – events, sequences, stratotypes of major boundaries, interval stratotypes, biozones, chronostratigraphy and 'absolute' dating, type sites of broad significance, onothems and erathems, palaeomagnetic evidence, etc. (E)
2. Palaeoenvironmental - past climate, global sedimentary geology, fossil indicators, sedimentary events and processes (C)
3. Palaeobiological - macro- and micro-animals and plants, problematic traces, stromatolites, evolution (A)
4. Igneous and metamorphic events and provinces; igneous, metamorphic and sedimentary petrology, textures and structures (D)
5. Mineralogical: processes and species (F)
6. Economic - of all types, intrusive, extrusive, strata-bound. Diamond kimberlite pipes. Metallogenic processes through time, metallic and non-metallic sources, mines and quarries (H)
7. Structural - major tectonic or gravity structures (G)
8. Continental/Oceanic-scale geological features. Tectonic plates and margins etc. African Rift, Antarctic Rift, island arcs, San Andreas Fault. Features which can often be best seen from space (L)
9. Relationships - tectonic plates, terrains (J)
10. Submarine - oceanic and continental shelf. Black smokers, deep trenches, sea mounts, fault scarps (M). Geomorphological features and erosional and depositional processes - landforms and landscapes, desert, cave, karst, volcanic, rivers, coastal, glacial and periglacial, soils etc (B)
11. Astroblemes, evidence of extra-terrestrial intervention, meteorite craters (K)
12. Other - e.g. historic, for development of geological science (I)

(Modified after GILGES: letter notation after COWIE, 1993)

Mem. Descr. Carta Geol. d'It.
LIV (1999), pp. 61-65

Environmental factors as an ulterior motive for the protection of the prehistoric archaeological patrimony

Fattori ambientali come ulteriore motivo di protezione del patrimonio preistorico archeologico

ANZIDEI A.P. (*)

The concept of the protection of archaeological goods, as formulated by the Italian national law 1089/39 and acknowledged by the Minister for the BBCCAA since its establishment in 1975, has had essentially as its objective the good in its definition as a monument or complex of archaeological importance or as a work of art.

In recent years, the level of development reached by prehistoric archaeology, in close relationship with paleontology and geology, has contributed to expanding the definition of the good to be subject of protection. It is no longer identifiable only with the visible structure, the work of man and only testimony of his presence. Instead it begins to affect, in its globality, that which is linked to human activity beginning in the very distant past, not out of context but inseparably connected with the geologic formations which contain them and have permitted their conservation to the present.

The concept of the archaeological complex becomes consequently enlarged and therefore necessarily assumes different connotations according to the period to which it is referred. The archaeological evidence relative to prehistory is not, in fact, for its nature documented by remains of walled structures (commonly called "ruins"), as happens in the historic period.

The protection therefore of the objects which affect paleontology and prehistory, as provided in the first art. of law 1089/39, cannot be limited to single palaeontological or archaeological finds, but necessarily, from the moment in which that object is found in its original environment, it must include the environmental context which has permitted its conservation and can allow for its interpretation.

The data which makes the reconstruction of human cultures in such an ancient phase possible derive infact from the geological, pedological, palaeontological, palaeobotanical, etc., data as a whole, which consequently contributes to form a coherent complex.

The environment therefore, of which law 1497/1939 provides protection, in particular cases in which it presents conspicuous characteristics of natural beauty or geological uniqueness, comes to assume a value in as much as it appears closely enough connected with the archaeological or palaeontogical resource to allow for a global interpretation.

The significance that the environment holds in the proposed legislation of archaeological protection is particularly underlined by the law of landscape-monumental importance 431 of 1985, better known as the "Galasso" law, with which it acquires a cultural connotation and is protected due to its close connection with the archaeological good.

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The "ruin" and the landscape come therefore to constitute an inseparable whole, where the archaeological monument, the morphology of the land and the frame of the vegetation are closely interconnected. The landscape also assumes archaeological relevance in as much as it perpetuates the morphological and landscape conditions which permitted the establishment and development of man's activity, of which the monument is the archaeological evidence. An evolution of this concept, no longer linked to the traditional view of the resulting ruin is documented by the ministerial memorandum of 6/12/95 which recognizes the validity of the landscape/archaeological restraint even in the areas not characterized by recovered archaeological presence. Therefore the archaeological landscape is given particular significance, which more than the single ruin, perpetuates those morphological and landscape characteristics which allowed for ancient human settlement. A landscape that has remained intact through the millennia and offers a key to the interpretation of ancient civilizations acquires consequently an "archaeological" value and can moreover be protected through the application of art. 2 of the law 1089/39.

This is why therefore the historical-archaeological environment, should not be considered differently from that landscape/naturalistic, and in both cases they are subject to protection by the part of the State.

The inseparable link between the monument and the surrounding environment is also contemplated by art. 21 of the same law 1089, which provides for the application of an indirect restraint on the lands confining those where the monument to protect is located; the integrity of the monument is consequently protected by the preservation of the surrounding environment.

The protection action for the things relating to paleontology, prehistory and ancient civilizations seems more complex, even if it is contemplated in the art. 1 of law 1089/39.

This article, in fact, does not value the inseparable relationship between the palaeontological and prehistoric goods with those environmental (geological) which assumes however a rather different connotation from that provided by art. 1, lett. m of Law 431/85 - in which these are inserted.

The "Soprintendenza Archeologica" of Rome in recent years has proceeded with an action of safeguarding the territory with particular reference to the prehistoric and palaeontological presence which has numerous traces aboveall in the northwest zone near the Via Aurelia and in the part of the territory south of Rome. In particular, in the territory of Castel di Guido, where the geologic conformation of Pleistocene age is conserved still intact, in the strata attributed to the "Aurelia Formation" have been identified concentrations of lithic material and finds of fossilized fauna, many of which were protected by law 1089/39.

Considering the inseparable relationship between the prehistoric and palaeontological presence with the geologic strata in which they are contained, the protection activity was directed in particular to the conservation of the complex seen in its entirety. In this way, it was possible to restrain the quarries located near the "Quartacci" at Vitinia, a suburb of Rome. Of these was recognized both the particular geologic and palaeontologic importance; from the exposed outcrop, infact, it was possible to reconstruct the almost complete sequence of geological events that happened in this part of the territory of Rome during the Middle and Upper Pleistocene. The presence of fossilized fauna in strata permitted to reconstruct the variations, in relation to the environment, inserted in a precise chronological framework.

Along with the program of territorial protection, the "Soprintendenza Archeologica" has undertaken a series of archaeological excavations of Pleistocenic deposits, preliminary to their conservation and public fruition.

In particular, the excavation and protection activity is concentrated on the two deposits of La Polledrara of Cecanibbio and Rebibbia-Casal dé Pazzi, in which the very rich archaeological and palaeontological documentation is not attributable only to the geologic structure. The two deposits consequently testify the very close connection of the palaeontological and prehistoric good to protect along with the geological environment which allowed for its conservation and results indispensable for its interpretation.

The deposit of La Polledrara of Cecanibbio is found in the north-western part of the territory of Rome, ca. 83 m above sea level, on the watershed of the rivers Arrone and Galeria near the twentieth kilometer of the Via Aurelia (fig. 1, 1). According to archaeological data acquired in the course of various excavation campaigns and geopedological investigations carried out, the deposit was associated with a fluvial-marsh palaeoenvironment, and in particular, with an ephemeral water course with a meander-form deve-

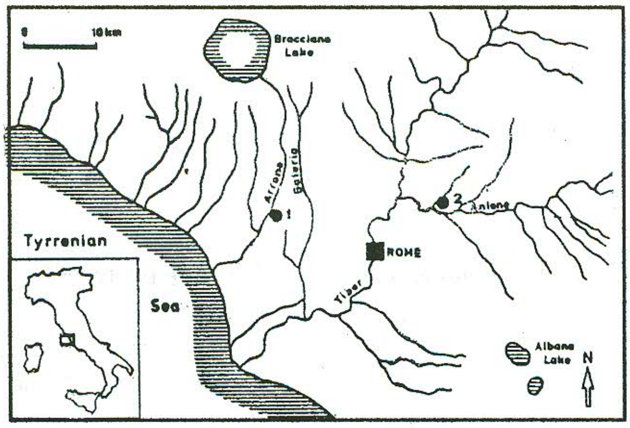

Figure 1. – Location map of the Pleistocene sites of La Polledrara di Cecanibbio (1) and Rebibbia-Casal de' Pazzi (2)

– *Mappa di localizzazione dei siti Pleistocenici de La Polledrara di Cecanibbio (1) e Rebibbia-Casal de' Pazzi (2)*

lopment, which flowed in a N-S direction, developing in a practically flat landscape.

From a stratigraphical point of view, the site is included in the terminal series of the pyroclastic deposits of the Sabatino volcanic complex, located to the northwest of Rome, and covers a ignimbritic strata known as "Tufo rosso a scorie nere", dated to ca. 430,000 years. The deposit was associated with a period preceding the Aurelia Formation, correlated with the isotopic stage 10 and can therefore be dated to more than 300,000 years.

The excavation has brought to light ca. 650 square meters of deposit, consisting of the ancient river bed, and its eastern margin, let alone a small adjacent area, probably more recent, with deposits formed by a very low energy water flow (fig. 2).

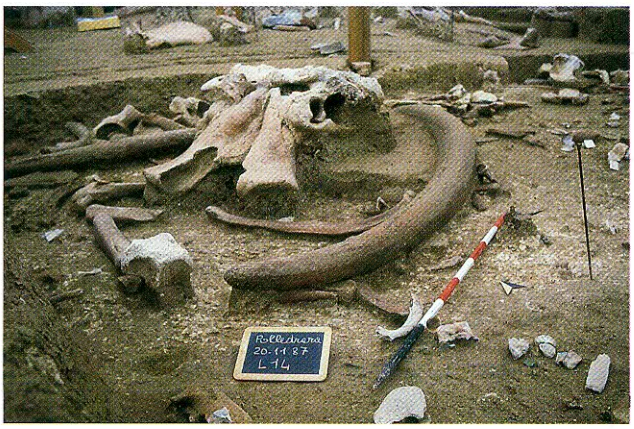

Figure 2. – La Polledrara : detail of the palaeosurface with the skull of an adult male *Elephas*

– *La Polledrara: dettaglio della paleosuperficie con il teschio di un Elephas maschio adulto*

The central incision of the river gradually joins the margin which presents a sinusoid trend and was partially disturbed by modern plowing.

A large number of faunistic finds, over 7,000, were on the palaeosurface, accumulated in various levels in the central channel, and dispersed on only one level in the marginal zones. The bones were successively covered by the limno-tuffite derived from the reworking of the pyroclastic products.

The fossilization of the finds took place by the transformation of the bone tissue in fluoroapatite, indicated by the diffractometric analysis, whose formation was linked to the post-volcanic hydrothermal activity.

The bones are essentially of *Palaeoloxodon (Elephas) antiquus* and *Bos primigenius*. There are also *Cervus (Cervus) elaphus, Equus caballus, Canis* aff: *Lupus* present. The faunal assemblage is composed essentially of the remains of animals that, dead on the banks, were then transported by the water and dislocated in part along the marginal areas. The presence of a few hundred lithic instruments (a few on bone) and the remains of a wolf indicate, however, the presence of other agents, among which man and predatory animals, which contributed to the dislocation and accumulation of the bones.

In an area, referable to an environment of marsh character, were identified the remains of at least two elephants with very fresh surfaces and in partial anatomic articulation. The excavation, still unfinished, seems however to indicate a certain sequence: a first phase characterized by a current that chaotically transported the bones, particularly of *Elephas* and *Bos*, followed by a phase with a stronger current which locally eroded and remodeled the river bottom. To this follows a final phase with very low energy water flow, where the animals must have gotten mired in the mud. It is interesting to note how the lithic instruments coming from this level, besides having a fresh surface, conserve still, in part, use wear traces.

The environmental, palaeontological, taphonomic and archaeological aspects of the deposit contribute to increase its scientific importance. Its topographic position in an area still intact of the Roman territory suggested the idea of in situ conservation of the deposit and its possibility to become a museum, which should be enacted with the financing of the "Giubileo 2000".

A second deposit, where a museum project, even with numerous difficulties, is being actualized, is the deposit of Rebibbia-Casal dé Pazzi, identified in 1981, and located instead within the urban area of Rome, between Via Nomentana and Via Tiburtina, ca. 32 m s.l.m. on a middle terrace of the lower valley of the Aniene River, a tributary of the Tiber (fig. 1, 2).

The deposit is above the "Tufo litoide lionato", a pyroclastic product of the "Vulcano Laziale", and consists of a segment of an ancient river bed incised in the strata of Tuff. The initial phase of the river, characterized by a strong river current, modeled the river bed in the bank of tuff after having eroded the covering level of a lacustrine strata, which is conserved, in the area of the excavation, only in isolated blocks (fig. 2).

The river channel was successively filled with pebbles and pyroclastic sands in which were included faunal finds and lithic industry.

The deposit belongs to the Vitinia sedimentary cycle, referable to the isotopic stage 7 or a slightly preceding period.

An ESR dating provided a date of 260,000 years from the present, while a date taken on bos teeth coming from the deposit by isoleucine epimerization provided a date of 360,000 ± 90,000 from the present.

Even if the faunal remains, consisting of over 2,000 finds, were transported by the current and therefore found in secondary deposition, they represent a good sample of local fauna. It refers mainly to remains attributable to *Palaeoloxodon (Elephas) antiquus, Bos primigenius, Hippopotamus ex gr. amphibius, Dicerorhinus sp., Cervus elaphus, Canis cfr. lupus, Capreolus capreolus, Crocuta crocuta, Equus caballus*, as well as aquatic birds.

From the lowest strata of the fill comes also a fragment of parietal bone attributable to an ancient form of *Homo Sapiens*.

The lithic industry, essentially in flint, consists of ca. 1,500 artifacts, for the most part on flake; however the instruments obtained from cores or pebbles are numerous. This industry, which can be culturally attributed to a late phase of the Lower Paleolithic, presents some technically evolved characteristics which makes them similar to the other protopontinian industries of the lower valley of the Aniene.

The particular importance of the deposit, in both its geological and archaeological aspects, has focused the action of protection not only toward its conservation by the application of an archaeological restraint, but also towards a museum project. This, organized by the common accord of the "Soprintendenza Archeologica" and the Municipality of Rome, and notwithstanding the difficulties, both economic and bureaucratic which caused a suspension of works for various years, seems finally on the way to being actualized. The last testimony of the Pleistocene deposits of the lower Aniene valley, still undamaged by urban development can be nevertheless conserved as testimony of the most ancient history of the territory of Rome and its settlement.

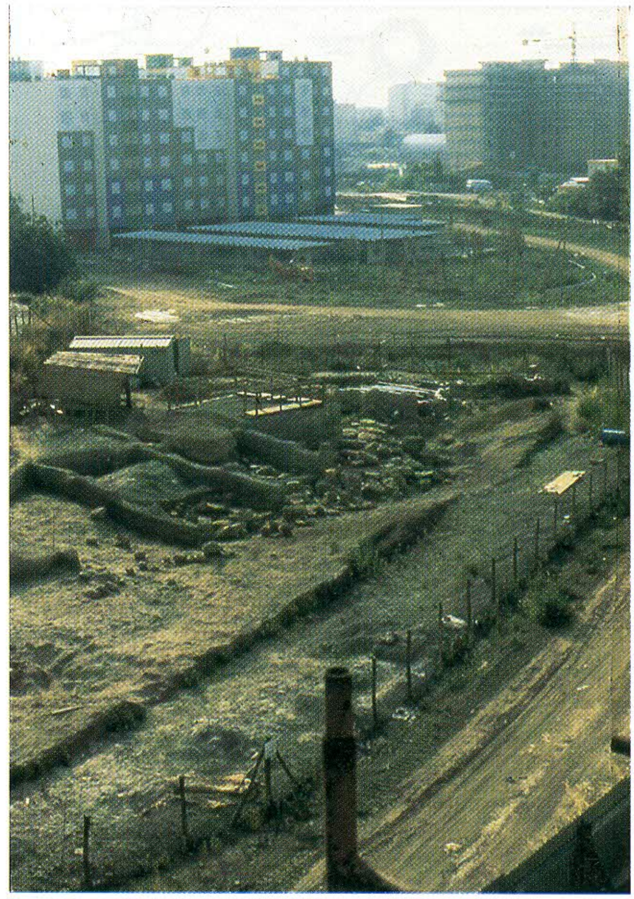

Figure 3. – Rebibbia-Casal de' Pazzi: general view of the rocky river bed

– *Rebibbia-Casal de' Pazzi: veduta generale del letto roccioso del fiume*

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Protection of Holocene travertines in Southern Poland
La protezione dei travertini olocenici nella Polonia meridionale

ALEXANDROWICZ S.W. (*)

ABSTRACT - Calcareous tuffs and travertine accumulated during the Holocene are rich in fossils indicating changes of environment. Several outcrops of these deposits have been described from Southern Poland. The most interesting ones occur in the Cracow Upland, a few of them are situated in protected areas. The sequence of calcareous sediments from the Raczawka stream valley, particularly rich in molluscan assemblages (described in detail), will be promoted for inclusion in the international list of geological heritage.

KEY WORDS: Holocene, travertines, molluscan fauna, geological heritage, Poland.

RIASSUNTO - I «tufi calcarei» ed i travertini accumulatisi durante l'Olocene sono ricchi di fossili, il che sta ad indicare cambiamenti nell'ambiente. Parecchi affioramenti di questi depositi sono stati descritti nella Polonia meridionale. I più interessanti si trovano nell'altipiano di Cracovia, e pochi di loro sono situati in aree protette. La sequenza di sedimenti calcarei nella valle fluviale del Raczawka, particolarmente ricca di molluschi descritti in dettaglio, sarà candidata all'inserimento nella lista internazionale del patrimonio geologico.

PAROLE CHIAVE: Olocene, Travertini, Fauna di molluschi, patrimonio geologico, Polonia

1. – INTRODUCTION

Late Quaternary calcareous tufa and travertines have been reported from several localities situated throughout Southern Poland, mainly from the Cracow Upland, the Holy Cross Mountains and the Polish Carpathians. They was deposited during the Holocene in narrow valleys and gorges within karst regions. The age of these sediments was established with the radiocarbon method supplemented by analysis of stable isotopes (C-13, O-18). Rich and differentiated molluscan assemblages have been found in all outcrops. They can be used as indicators of sedimentary conditions and changes of environment controlled by both the climate and the human impact. Other organic remains, such as bones and teeth of vertebrates, carapaces of ostracods, leafs of trees and fragments of trunks, occur additionally. The best and most instructive profiles of these deposits should by protected as documents of the youngest history of the earth and environment as well as of the relations between geological processes and the activity of man.

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2. – CALCAREOUS TUFA OF THE CRACOW UPLAND

The Cracow Upland encloses the south-eastern part of the Silesian-Cracow Monocline. Mesozoic formations represented mainly by limestones and marls of the Middle Triassic, Upper Jurassic and Upper Cretaceous dip gently north-eastward. A small anticline formed of Devonian and Lower Carboniferous limestones and dolomites (Dome of Dêbnik) crop out in the south-western part of this region, bordered southward by a system of faults, troughs and horsts connected with the alpine tectonic. The last mentioned are distinctly reflected in the structural relief. Deep and narrow valleys of streams cross the elevated part of the upland forming the picturesque karst scenery with an old (Tertiary) planation surface, a lot of limestone klippes, rocky terraces, caves, hollows and springs. During the last glaciation the whole area was covered with loess. At the termination of Vistulian, after the phase of erosion and the downcutting of stream channels, a considerable part of the loess was removed and only in a few places traces of Late Pleistocene dry valleys (dellen) are preserved, as loess terraces.

The deposition of calcareous sediments started at the beginning of the Holocene as a result of the activity of beavers. Small dams formed by these animals of branches and trunks of trees were grown over with green algae, precipitating calcium carbonate. Small water bodies formed behind such dams were gradually filled with fine-grained calcareous sediments (tufa). During a few thousand years dams were constructed upward by beavers and transformed into travertines after the recrystalisation of carbonates, the thickness of tufa growing greater and greater reaching four, six or even ten meters. In the Late Holocene dams were dissected and damaged by floods and increasing erosion, effected by the deforestation of the Upland during the Neolithic land occupation, the Lusitian Culture or Middle Ages. Travertine terraces with outcrops of Holocene calcareous deposits are preserved as relics of these processes.

Twenty profiles of calcareous tufa and travertines are noteworthy. A few types of lithostratigraphic sequences have been noted (ALEXANDROWICZ, 1983). The first of them begins with hard porous trevertines alternateing with nodular tufa. Yellow and grey calcareous tufa abounding in shells of molluscs and carapaces of ostracods closes this sequence (ALEXANDROWICZ, 1985). In the second type nodular tufa alternates with silty tufa as well as with peaty silts. Yellow silts and grey marly tufa with traces of a buried soil occur at the top. Numerous intercalations of calcareous sand and fine gravel between white and grey tufa characterise the third type of the sequence, the next one is composed exclusively of white and yellow mollusc-bearing calcareous tufa. In large river valleys the described deposits occur as intercalations (10 - 40 cm) within silts and peaty silts, covered with alluvial loam.

In all outcrops calcareous tufa contain shells of molluscs. Particular molluscan assemblages are composed of characteristic species living in different environments. They have been studied in detail according to methods described by LOZEK (1964) and the Author (ALEXANDROWICZ, 1987). Five ecological groups of species (E) have been distinguished: shade loving snails (E 1-3), open-country snails typical of sunny and even kserothermic habitats (E 4-5), catholic species living in both shady and open environments of more or less humid background (E 6-8), higrophile snails typical of swamps & marshes (E 9) and water molluscs (E 10). Relations between these groups (counted as species and specimens, and illustrated by malacospectra MSS and MSI respectively), give the evidence about changes of environment and sedimentary conditions (LOZEK, 1964; EVANS, 1972; ALEXANDROWICZ, 1987).

Sequences of molluscan assemblages are distinctly differentiated. Three main types of malacological sequences can be distinguished. The first one begins either with a community of open-country and higrophile snails or by a community of water molluscs (Early Holocene). It passes upward into a fauna enriched in woodland snails (climatic optimum) and finally into a fauna with catholic and open-country species (Late Holocene). Such a succession is connected with calcareous tufa accumulated in quite narrow valleys and gorges. The second type contains mainly open-country snails dominating through the whole profile, accompanied by catholic species or snails living in swamps, marshes and alder forest. This succession occurs in tufa deposited at the bottom of relatively large valleys. The third type associated with sediments of permanent water bodies is characterised by water molluscs as the main component of all assemblages. Intermediate sequences of communities have been observed at a few localities.

3. – CALCAREOUS TUFA IN THE RACLAWKA STREAM VALLEY

The Raclawka stream valley crosses the Upland between villages of Raclawice, Dubie and Rudawa, about 20 km north-westward of Cracow. Upper Jurassic limestones and Devonian/Lower Carboniferous limestones are visible along the upper and middle reaches of the stream. Four travertine steps, with ancient water basins filled with calcareous tufa, have been distinguished in this valley (ALEXANDROWICZ, 1983; RUTKOWSKI, 1991). The most interesting of them, situated 1 km upstream of the village of Dubie is up to 9 m high (SZULC, 1986). It forms a terrace with a very instructive outcrop of calcareous tufa, representing nearly the whole Holocene (Fig. 1).

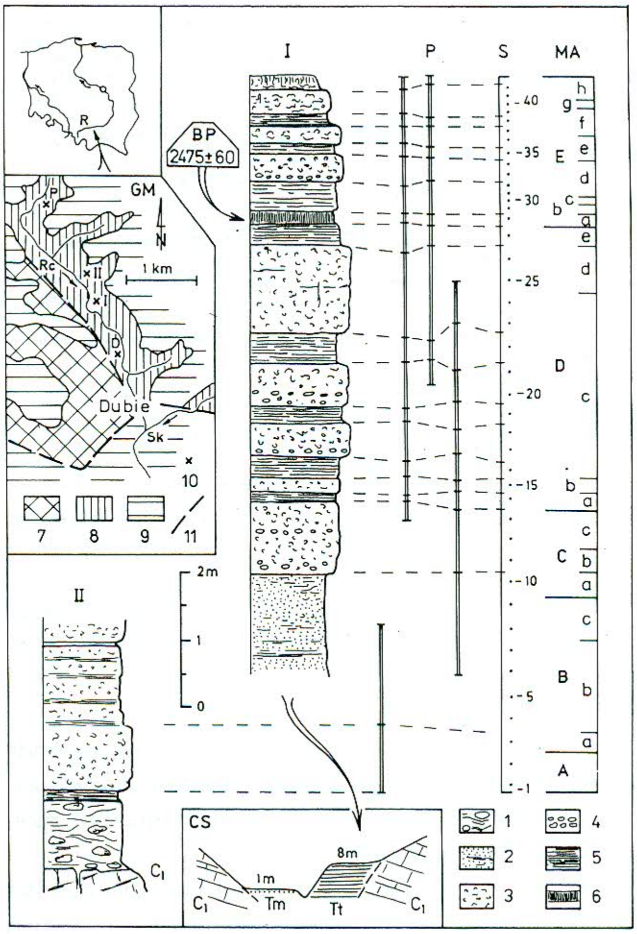

Fig. 1. – The outcrop of tufa and travertines in the Raclawka stream valley. I, II - sequence of sediments, P - profiles, S - samples, MA - molluscan assemblages, 1 - silty clays, 2 - fine-grained tufa, 3 - nodular tufa, 4 - gravel, 5 - silts and silty tufa, 6 - buried soil; GM - geological map: 7 - Devonian, 8 - Lower Carboniferous, 9 - Upper Jurassic, 10 - location of profile, 11 - faults; CS - cross section: C1 - Lower Carboniferous, Tt - travertine terrace, Tn - flood terrace.

– L'affioramento di tufo e travertini nella Valle fluviale di Raclawka. I,II - sequenza di sedimenti, P - profili, S - campioni, MA - raccolte di molluschi, 1 - argille siltose, 2 - tufo a grana fine, 3 - tufo nodulare, 4 - ghiaia, 5 - silt e tufi siltosi, 6 - suoli sepolti; GM - mappa geologica: 7 - Devoniano, 8 - Carbonifero Inferiore, 9 - Giurassico Superiore, 10 - posizione di profilo, 11 - faglie; CS - sezione trasversale: C1 - Carbonifero Inferiore, Tt - terrazzo di travertino, Tn - terrazzo alluvionale.

The sequence of sediments overlying Carboniferous limestones is as follows (in reverse stratigraphic order):

1) silty clays with limestone lumps enriched in humus at the top (0.5 - 1 m);
2) silty and fine-grained calcareous tufa (1 - 1.5 m);
3) nodular tufa intercalated with limestone gravel (1 m);
4) silty- and fine-grained tufa alternating grey calcareous silts (2 - 2.5 m);
5) nodular tufa with thin layers of stromatolites (1 - 1.5 m);
6) grey silts enriched in humus with traces of the buried soil (0.5 - 1 m);
7) fine-grained tufa with oncoids and stromatolites, alternating with yellow silts (1.5 m).

Fragments of travertine dam are preserved in the southern part of the outcrop. Calcificated trunks of trees incorporated into hard, porous algal bioherm are well seen.

The age of the described deposits has been measured with the radiocarbon method. In three samples it was established using the organic fraction, whereas in nine samples the apparent age was estimated with the analysis of the carbonate fraction (PAZDUR, 1987). Two datas derive from the lowermost part of the sequence: 9.880 ± 130 BP (Gd-4065) and 9.820 ± 100 BP (Gd-5287) while the third, from the upper part (from the buried soil): 2.475 ± 60 BP (Gro-584). The apparent age of oncoids and stromatolites from the uppermost part of the profile was established with the measurement of the carbonate fraction as: 1.900 ± 360 (Gd-1811) and 1.970 ± 350 (Gd-3028). According to these results calcareous tufa and travertines from the site in question have been deposited since the beginning of the Holocene till approximately the Middle Ages.

Rich and differentiated molluscan assemblages were previously described by Alexandrowicz (1983). The detail malacological analysis presented now is based on 42 samples (fig. 1-S). The material includes 64 taxa of snails and bivalves including species of ten ecological groups. Particular malacocoenoses A-E, are characterised by molluscan spectra MSS and MSI (fig. 2). The sequence is composed of following assemblages (from the bottom upward):

A - fauna dominated by water molluscs with a considerable content of *Lymnaea truncatula* and *Gyraulus laevis*;

B - fauna with shade-loving snails (*Discus ruderatus, Acicula polita, Vitrea crystallina, Bradybaena fruticum*), open-country species (*Vallonia pulchella*), catholic species (*Punctum pygmaeum, Vertigo substriata*) and water molluscs;

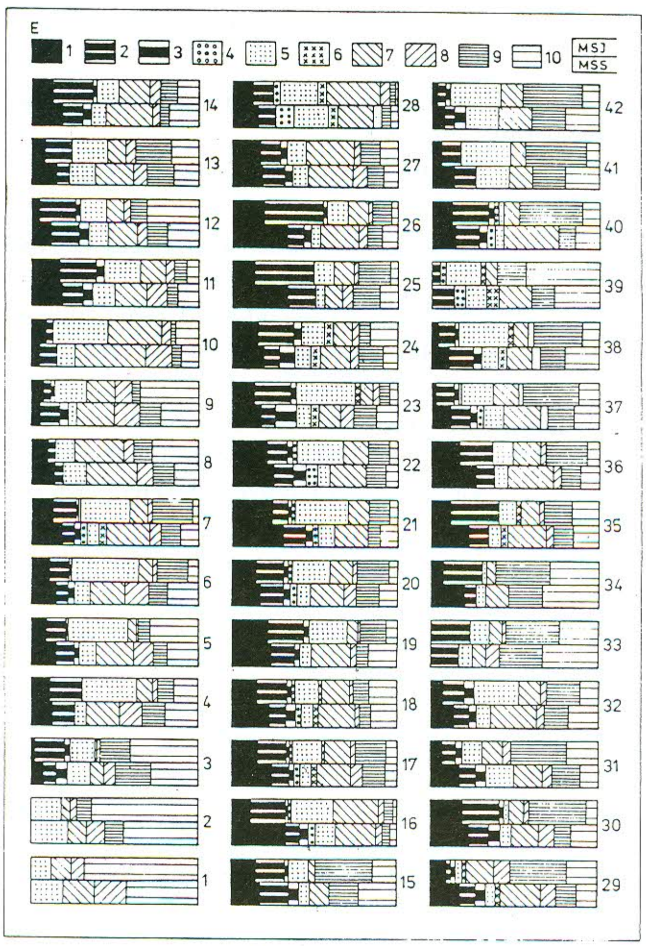

Fig. 2. – Malacospectra of molluscan assemblages of the calcareous tufa at Raclawka. E - ecological groups of molluscs: 1 - woodland snails, 2 - bushland snails, 3 - snails of moist forest, 4 - xerophile species, 5 - open-country snails, 6 - species of dry habitats, 7 - catholic snails of moderately humid habitats, 8 - catholic snails of humid habitats, 9 - species of swamps and marches, 10 - water molluscs, MSI - malacospectra of specimens, MSS - malacospectra of species.

– Spettro malacologico dell'associazione di molluschi dei "tufi calcarei" a Raclawka. E - gruppi ecologici di molluschi: 1 - specie boschive, 2 - specie di macchia, 3 - specie di foresta fluviale, 4 - specie xerofile, 5 - specie di campagna, 6 - specie di habitat secco, 7 - specie di habitat moderatamente umidi, 8 - specie di habitat umidi, 9 - specie di paludi e di zone di confine, 10 - molluschi acquatici, MSI - malacospettri di campioni, MSS - malacospettri di specie.

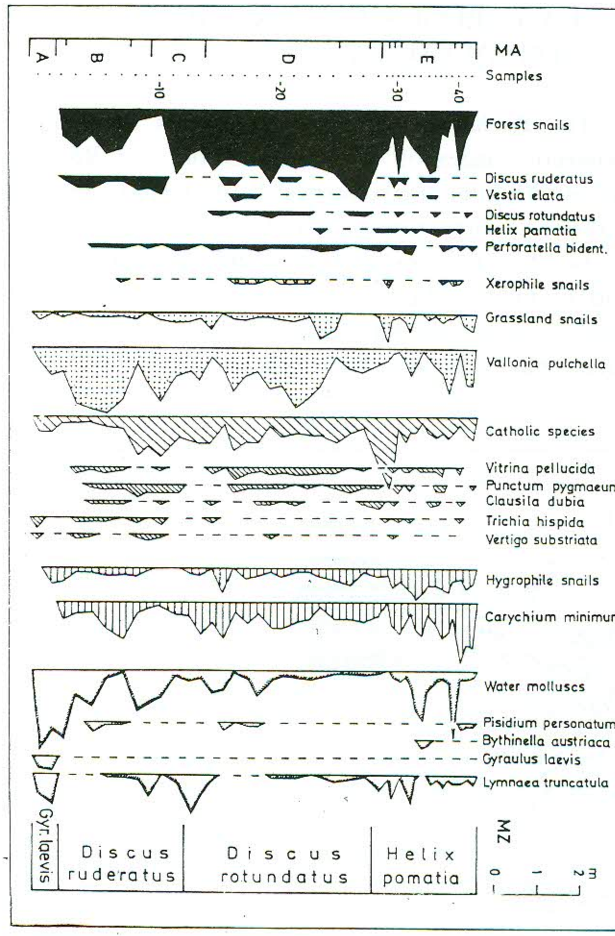

Fig. 3. – Malacological diagram of the Holocene tufa exposed in the Raclawka stream valley. MA - molluscan assemblages, MZ - malacostratigraphic zones.

– Diagramma malacologico dei tufi olocenici esposti nella Valle fluviale di Raclawka. MA - associazioni di molluschi, MZ - zone malacostratigrafiche.

C - fauna distinctly enriched in snails living in shady and partly shady habitats (*Acicula polita, Acanthinula aculeata, Vitrea crystallina*) with a changing content of molluscs of other ecological groups;

D - the richest fauna, with a considerable number of woodland snails (*Discus rotundatus, Discus perspectivus, Vitrea transsylvanica, Ruthenica filograna, Vestia elata, Isognomostoma isognomostoma*) accompanied by catholic and higrophile species (*Nesovitrea hammonis, Carychium minimum, Zonitioides nitidus*);

E - fauna characterised by a changing content of shade-loving snails (*Aegopinella pura, Vitrea diaphana*), open-country species (*Vallonia pulchella*), higrophile snails and water molluscs (*Valvata cristata, Lymnaea peregra, Anisus leucostomus*).

Four malacostratigraphic zones defined as "nominal zones" (ALEXANDROWICZ, 1987) have been distinguished based on the molluscan diagram (fig. 3). The oldest one, Zone with *Gyraulus laevis*, corresponds with the Preboreal Phase of the Holocene or with its early part. The next one, Zone with *Discus ruderatus*, reflects the increasing afforestation of the area during the Boreal Phase. The Zone with *Discus rotundatus*, typical of the climatic optimum, encompasses the Atlantic Phase and a part of the Subboreal Phase at least. The youngest one, Zone with *Helix pomatia*, is connected mainly with the Subatlantic Phase.

This sequence of molluscan assemblages reflects particular stages of the environmental evolution of the Cracow Upland during the Holocene. The afforestation indicated by the fauna with *Discus ruderatus* and *Discus rotundatus* corresponds with the warming and increasing humidity of the climate: the occurrence of snails typical of sunny, xerothermic habitats (*Truncatellina cylindrica, Truncatellina costulata, Cepaea vindobonensis*) is connected with the deforestation caused by man. Analysis of stable isotopes carried out on samples from the profile, and interpreted by PAZDUR *et alii* (1988), are another indicator of climatic changes.

4. – PROTECTION OF HOLOCENE CALCAREOUS DEPOSITS

Late Quaternary tufa and travertines are particularly interesting and noteworthy as deposits rich in fossils. They document the youngest geological history of the region as well as changes of the environment, habitats and ecosystems controlled by both the climate and human impact. These sediments have been studied from different points of view including the course of accumulation, remains of plants and animals, geochronology and palaeotemperatures. Profiles recording many characters are important as type-sequences, used in palaeogeographical reconstructions. The most important ones should be protected for science and education as sites of local, regional or even international interests.

A few outcrops of Holocene tufa and travertines have recently been protected in the Cracow Upland. One of them occurs in the Ojców National Park. A hard bed of travertine forms a small waterfalls while its sequence of mollusc-bearing tufa is accessible in the right bank of the Saspówka stream (ALEXANDROWICZ, 1983). The Pradnik-type succession of molluscan assemblages has been defined in this profile (ALEXANDROWICZ, 1985).

Five sites of calcareous deposits are situated in nature reserves inside the large area protected as a landscape park. One outcrop is situated in the Eliaszówka Nature Reserve near Krzeszowice, while the remaining four - in the Raclawka Nature Reserve (two in the Raclawka stream valley and two - in the Szklarka stream valley). A few other localities will be protected in a short time as geological documentary sites or as nature monuments. Very interesting sites occur near Wolbrom, 30 km northward of Cracow. One of them, the gorge in Trzebienice, crossing calcareous tufa accessible in several outcrops, will be proposed as a nature reserve, while the other, an outcrop in Rzerzuœnia representing the travertine terrace, should be protected as a documentary site. The most of the mentioned localities are of regional importance, but the main outcrop in the Raclawka stream valley, described above in detail, can be pointed out as an exceptional one. It has been selected as a site to be promoted to the international list of geological heritage. Such a suggestion is supported by the following motives:

- the profile encloses both the travertine dam and tufa filling the ancient water body;
- several lithological types of tufa and sedimentary structures, including organogenic components (oncoids and stromatolites) can be observed;
- a buried soil with traces of pottery occurs in the upper part of the outcrop;
- it has a sequence of particularly rich molluscan assemblages characterising changes of environment during almost the whole Holocene: it has been described as the type-succession (the Raclawka-type succession);
- several samples have been dated with the radiocarbon method and analysis of stable isotopes was additionally carried out.

The main outcrop of tufa and travertines in the Raclawka stream valley is the most representative site of such sediments in Poland. A few other interesting sites are known from the Holy Cross Mountains, the Czestochowa Upland and Carpathians (ALEXANDROWICZ & ALEXANDROWICZ, 1995a; 1995b). Some of them will be protected as documentary sites.

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