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ScienceDirect
Earth-Science Reviews 86 (2008) 247–254
EARTH-SCIENCE REVIEWS
www.elsevier.com/locate/earscirev

Earth reflections

Geological education of the future

A.J. van Loon

Institute of Geology, Adam Mickiewicz University, Maków Polnych 16, 61-606 Pozna, Poland

Received 24 July 2007; accepted 22 August 2007
Available online 29 August 2007

Abstract

Several developments cause that field practice of students becomes minimized in most countries. The most important reasons are, direct or indirect, financial short-sightedness, an ever increasing population pressure, vandalism, and counterproductive legislature. The diminishing field experience forms a threat for the capability of future generations of earth scientists to optimize exploration of all kinds of natural resources, thus also threatening society. As it is unlikely that the present-day tendency of diminishing availability of excursion points and areas for field work will come to an end, measures should be taken timely to preserve sites that are of educational (or scientific) value. National measures and international cooperation aimed at preserving our geological heritage, like realized already in, for instance, the US by the National Park Service and in Europe by ProGeo, form a step in the good direction. Dependency on such preserves will, however, change the education of earth scientists fundamentally. However unfortunate such a development may be, it is better than a future where geological education becomes impossible because essential parts of our geological heritage have been lost forever.

Keywords: geological heritage; education; preservation; exposures; geovandalism

1. Introduction

The earth sciences form part of the natural sciences, which are characterized by the fact that processes and phenomena are ruled by "laws" that have – at least for a significant part – been recognized by Man. The discovery of these laws and the understanding of their results as expressed in the world around us make it possible to predict features and phenomena (e.g. the occurrence of a hydrocarbons reservoir) with significant reliability. This is why the natural sciences are – in contrast to other disciplines – also called the "hard sciences".

The increasing insight into the laws that determine processes and features have greatly helped to understand that phenomena that are, at first sight, entirely different, can have much in common: a glacier and clouds, for instance, have the same chemical composition. The knowledge of laws in the various natural disciplines can also help to provide a context for phenomena. Meteorites are a good example: astronomers, physicists, chemists, biologists and earth scientist jointly have been able to explain their origin, the resemblances and differences between individual specimens, and the occurrence of specific features such as the so-called Widmanstätten structures (Fig. 1) that become visible in some types after polishing.

Within the natural sciences, the earth sciences take a special position, as all processes that contribute to geological phenomena belong, essentially, to one or more of the other natural sciences: thus, the earth sciences

E-mail address: tom.van.loon@wxs.nl.

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doi:10.1016/j.earscirev.2007.08.005

Fig. 1. Polished iron meteorite with Widmanstätten structures. From Korotev (2007).

have, much more than the other hard sciences, a synthetic nature. In addition, almost all geological features result from a wide variety of processes and, consequently, most geological features are complex. As the relative influence of the many processes that underlie most of the geological features may vary greatly, the resulting individual geological features also show countless variations: no two mountain ranges or delta architectures are identical, and even a simple rock type like halite can have different appearances due to, for instance, impurities, diapiric or other deformations, or exposure to ionizing radiation resulting in a blue colour (Fig. 2).

Consequently, geology is less easily learned from textbooks than the other natural sciences. Education of students in the field is therefore essential. Without extensive field activities, the earth sciences – and thus also the earth scientists – have no future.

2. Threats to field activities

Whereas field work and excursions used to be a major part of geological education, it was, unfortunately, greatly diminished in the past few decades; certainly in Western Europe, but a similar development is noticeable almost worldwide. Thus, the earth-science education of our future professionals is severely threatened (cf. Gray, 2004). The reasons for the decrease in time spent by students in the field are numerous; the most important are lack of money due to short-sightedness, population pressure, vandalism and legislation.

2.1. Short-sightedness

It can only be regretted that the prime cause of decreased field education in most countries is a lack of money due to short-sightedness of both governments and universities. In The Netherlands, for instance, the percentage of the gross national product spent to education is declining already for many years, in spite of statements by the government that education is the base for future prosperity. Moreover, the distribution of the relatively diminishing amount of money over the various types of education is changing, and universities tend to get a steadily decreasing percentage of the available money. It may be true that the absolute amount of money for universities shows a slight annual increase, but this is insufficient to compensate for the inflation. And, what is worse, the increase in money for universities is not spent to better education of students, but rather it is used (and commonly even for more than 100%!) for the employment of ever more managers. This short-sightedness implies that earth-science students can obtain their degree nowadays with only a very limited amount of field experience.

2.2. Population pressure

A second reason for the diminishing field activities of earth-science students is the ongoing increase in

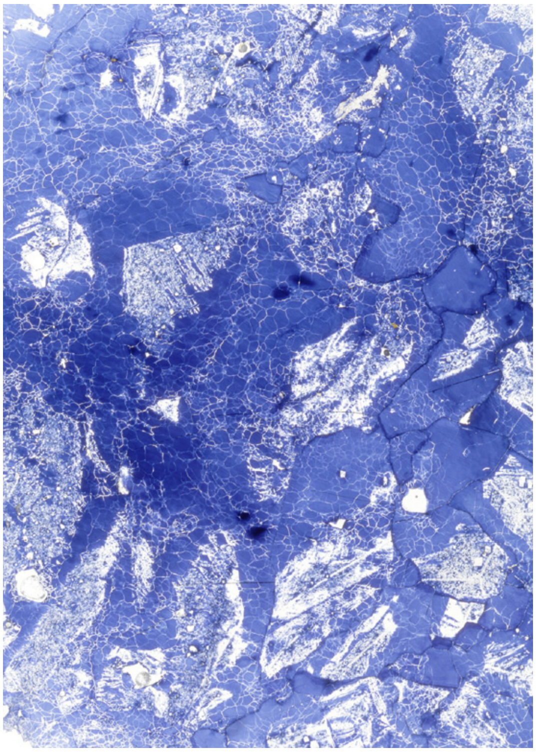

Fig. 2. Thin section of a Middle Triassic salt sample from a core near Hengelo (The Netherlands), photographed in transmitted light. The sample was gamma-irradiated at 100 °C, which is responsible for the blue colour. A few new, recrystallized, strain-free grains or grain regions are visible. Image width is 4 cm. From Schléder and Urai (2005). Image courtesy of Zsolt Schléder and Janos Urai, www.geol.rwth-aachen.de.

population pressure. Ever more space is needed for housing people, agriculture, industrial activities, and infrastructure. In densely populated areas, the possibilities for fieldwork therefore become increasingly limited, and authorities intend more and more frequently to forbid fieldwork in the remaining few “wild” areas (which are often cultivated!) because these should serve exclusively recreation.

Consequently, earth-science faculties become increasingly confronted with the necessity to arrange excursions and fieldwork far away, often even abroad. This has, obviously, financial consequences, and – as explained above – the financial means are decreasing rather than increasing.

The increasing population pressure is not only a problem for the earth sciences because areas become inaccessible, but even more because exposures and – not rarely unique – features are destroyed; sometimes because of lack of knowledge from the side of the responsible authorities, sometimes by negligence, and sometimes because it is unavoidable if costs for society should not be excessively increased. The problem with destroyed geological features is that they are commonly irreplaceable, not only because geological features are – almost by definition – unique, but also because both human-made and natural exposures are commonly the result of a relatively exceptional earth-scientific context (e.g. a bioherm that stands out in the field because the originally surrounding muddy marine sediments have been eroded away in the course of geological time).

In general, mining activities are carried out at an increasingly large scale (Van Loon, 2001) – because of cost reduction and because of the increasing demand by a growing world population – and in more and more less accessible (in original state) areas, because easily accessible resources are exploited and exhausted first. A result is that the numerous small exposures that used to exist in many areas are abandoned, and no longer can be used for field activities. The resulting lack of exposures also diminishes the possibility to show lateral facies changes in the field. Fortunately, mining activities can also contribute to earth-science education. Not only because large-scale quarries may reveal the geological context of all kinds of features, but also indirectly by their influence on the surroundings. This may lead to the earlier unexpected discovery of geological treasures. A fine example is the Cueva de los Cristales (Crystal Cave) near Naica (Mexico). This originally water-filled cave, which was discovered only because the regional groundwater level was lowered for the purpose of metal-ore mining, houses spectacular selenite crystals of great purity and of exceptional size, up to 12 m long (Fig. 3).

Fig. 3. Huge selenite crystals in the Cueva de los Cristales near Naica (Mexico). Photo La Venta/Speleoresearch.

It should be realized, however, that even such a site is threatened: when the mining activities will end, the pumping of groundwater may be stopped and the cave will eventually become inaccessible again.

2.3. Vandalism

Vandalism is an increasing problem in many present-day societies. For earth scientists, two types of vandalism are of direct importance, one of which might be stopped – or at least be reduced significantly – by proper measures.

The first type of vandalism consists of the same actions as found elsewhere in society. Private property is destroyed, gates in fences on farmlands are not closed again after passing, waste is left, and grafitti are painted all over. Numerous private persons and companies with interesting exposures and/or special earth-science phenomena on their property, who previously welcomed interested parties, therefore now refuse entrance, thus strongly diminishing the number of sites that can be visited during geological excursions.

The second type of vandalism is due to people who sometimes consider themselves as geologists, but who are merely merchants, and who might rather be called “geovandals”. They destroy rocks (sometimes in the wilderness, sometimes on private land, and sometimes even in natural or geological reserves), commonly on a fairly large scale – frequently blasting rocks with explosives – in order to collect fossils or minerals that they sell in shops, on fairs and, increasingly, through internet. Not only does this geovandalism result in measures by authorities and private persons to deny access to the sites involved, but it sometimes even results in the definite end of a scientifically or educationally highly valuable site.

Earth scientists should realize that it is in their own interest that they convince authorities to take severe measures against each type of vandalism that threatens our geological heritage. Fortunately, authorities have already punished the two largest cola companies after damaging geological research sites in the Himalayas for advertisement activities (Anonymous, 2002). More pressure from the side of the earth-science community is required, however, and earth scientists can easily help in practice. They should, for instance, stop buying fossils, minerals and other geological items if the salesman cannot prove beyond doubt that the item has been obtained in a both legally and scientifically and socially acceptable way (almost all museums follow this approach already). A boycott of "vandalism-obtained" items, in combination with severe penalties, can largely stop unwanted actions. This was proven convincingly for Chinese fossils. The illegal export of spectacular fossils – feathered dinosaurs (Fig. 4) and numerous other related fossils of great scientific value (a.o. Ji et al., 2004; Zhang and Zhou, 2004; You et al., 2006; Li et al., 2007) – from the Chinese Liaoning province has been greatly reduced since the export is carefully checked, since a debate on this topic has been started in the media (Dalton, 2004) and since the penalties have become so high that attempts to export these fossils illegally no longer are profitable. In Australia, the intentional destruction of fossilized footprints of prehistoric Man was punished with imprisonment (Pockley, 2000) and this seems to have largely stopped such destructive activities. Similar measures should therefore be taken worldwide.

Fig. 4. *Caudipteryx*, a feathered dinosaur. From Naish, 2007.

This does not imply, however, that *all* commercial activities should be boycotted. Commercial people/companies can do good work that can, as a rule, not been carried out well by universities or museums. The recent establishment of the Association of Applied Paleontologists that states to work according to good practice and following legislative rules, is therefore to be welcomed, although it remains a task for the geological community – which is understandably sceptical (Hopkin, 2007; Stokstad, 2007) – to check on a regular basis whether commercial objects have been obtained in a justifiable way, indeed.

2.4. Legal responsibility

A last major threat for field activities is legislation. An increasing number of countries has adapted the laws in such a sense that the owners of, for instance, a quarry are responsible for any accident that may happen to visitors, even if these visitors (e.g. a geological excursion) have signed a statement beforehand that they will *not* hold the owner responsible.

Many exposures pose risks, in the form of falling rocks, sliding walls, quicksand, etc. It has therefore always been good practice for earth scientists to have an adequate insurance against such accidents (although such an insurance does, obviously, not help to minimize the risk, but only its financial consequences). The fact that owners of a property are held legally responsible for accidents does therefore not serve any practical objective; it only makes it understandable that hardly any owners grant permission anymore to visit their site. This becomes a truly great problem for field activities in many countries, strongly reducing the opportunities to educate students in the field.

3. Geological heritage

The rapidly diminishing number of features that can be shown to students in the field greatly limits their experience and their capability to consider a geological feature in a wider earth-scientific context. This, in turn, diminishes their capability to carry out, as professionals,

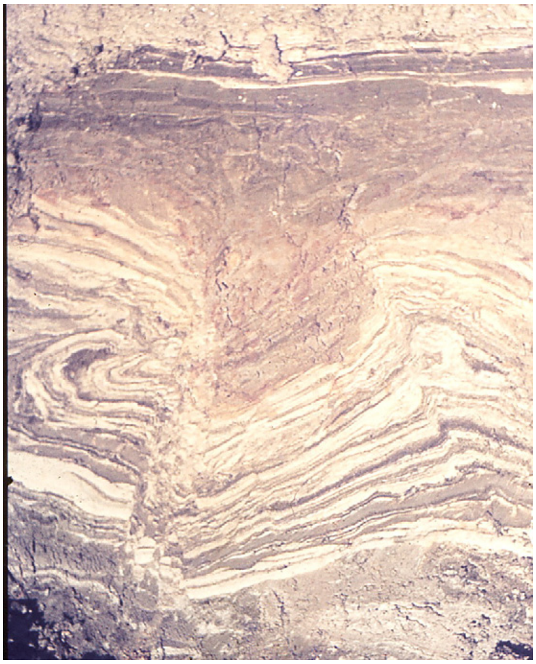

Fig. 5. One of the complex non-tectonic, non-seismic deformations in the 1200–1600 AD deposits from the then central Netherlands lagoon, considered worth in the 1980s to be preserved, but not traceable anymore due to negligence of the responsible authorities.

practice-oriented work, such as the exploration for specific resources. It is therefore of utmost importance that future generations of earth-science students will be able to participate in excursions and to carry out fieldwork. This can be achieved only if adequate measures are timely taken to preserve sites for excursions, as well as areas that can be used for mapping exercises, for specialist fieldwork, for collecting fossils, etc. This holds, obviously, not only for the education of students, but also for professional fieldwork aimed at collecting new data, developing new theories, and testing them, thus deepening our insight into the origin, the development and the present state of the earth. Insufficient insight into these aspects will limit the possibility to predict what impact specific natural processes or human activities will have on the environment, which risks may be involved, and how new resources can be found. If this would be no longer be sufficiently possible, there will come an end to the earth sciences, both as a science and as a prerequisite tool for the continuation of human civilisation.

Fortunately, an increasing number of earth scientists come – or have already come – to this insight, and more and more steps are being taken to preserve the geological heritage. In some countries, this preservation attitude has started already long ago, and sometimes with much success, such as in the case of the National Parks in the USA. Elsewhere, however, attempts to do so have largely failed, such as in The Netherlands, where some geological sites had been assigned a certain preservation and educational status (Gonggrijp and Boekschoten, 1981), but after the initiator, Gerard P. Gonggrijp, had died, most of these sometimes small (only a few m^2) sites were no longer maintained, and some sites with unique sedimentary structures (Fig. 5) cannot even been found back.

3.1. Combined international and national approaches

The necessity to preserve unique and valuable geological features – partly in the form of landscapes – has already been recognized early in the United States. In combination with other considerations this has led to the establishment of the National Park Service, and the result is an ever growing number of sites (apart from earth-scientific sites also objects of cultural and historical importance) that are well maintained, where research is carried out, where excellent education is provided through books, movies, videos, visitor centres, guided and non-guided tours, trails, etc. (Fig. 6). The activities of the National Park Service are, justifiably, so well received by the public that they have one great disadvantage: the number of visitors is growing so strongly that some limitations are already applicable to the access of several sites. Fortunately, the already large number of the parks is increasing steadily, and many parks extend over such a vast area that those who are interested in seeing often spectacular landforms, will be able to do so for a long time.

Fig. 6. The Great Sand Dunes National Park and Preserve: inland dunes of up to some 225 m high in Colorado. Proclaimed in 1932, the monument covers some 100 km^2 (NPF, 2001).

Comparable initiatives started, as a rule, much later on the other continents. Parks in Africa were, from the very beginning, focused on animals rather than on earth-scientific phenomena. Particularly during the past two decades, however, initiatives have been started in numerous countries to establish organisations aimed at the structured preservation of earth-scientifically interesting or valuable sites. In Europe, numerous initiatives have been taken, almost all on a national basis (see Gray, 2004). Not all these initiatives have proven successful, but many have reached recognition from both governments and public. The national or even regional approach by these preservation-oriented organisations implies that they all have their own philosophy, work in different ways, and do hardly profit from experiences gained elsewhere. There is, however, one organisation (ProGeo) in Europe that is distinctly growing, and that covers now most European countries. These include already Albania, Belarus, Bulgaria, Bosnia, Czech Republic, Croatia, Denmark, Estonia, Finland, Germany, Greece, Irish Republic, Italy, Kazakhstan, Latvia, Lithuania, Macedonia, Norway, Poland, Portugal, Rumania, Russia, Serbia and Montenegro, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and Ukraine.

ProGeo, which started formally in 1993 as a successor of the European Working Group on Earth-Science Conservation, is very much aware of the threats that rocks and landscapes are confronted with. As they state, "The record preserved in the rocks and the landscape is unique, and much of it is surprisingly fragile. Today it is threatened more than ever. What is lost can never be recovered, and therefore there is an urgent need to understand and protect what remains of this our common heritage". The aim of ProGeo (officially: European Association for the Conservation of the Geological Heritage) is to share knowledge, spread best practice and to support weaker partner organisations, and countries, where geoconservation is absent or poorly developed. The strength of this organisation is that the experts involved represent an international "think tank" that develops, also on the basis of practical implementations, guidelines for how to inventory what phenomena may be worth to be protected, as well as practical approaches. These findings are commonly available in print, but no national authority or organisation is forced to follow the guidelines: they are intended as help.

It turns out that this approach is most successful, considering the fact that many European countries now are developing strategies for the preservation of the geological heritage. Just like is the case with the National Parks in the USA, both small-scale exposures and vast landscapes are objects of study now, and numerous sites have already been indicated as heritage sites. The organisation of fairly frequent (generally accessible) meetings where new developments are discussed, appears to be highly effective and results in valuable data (see, for instance, ESC, 2005).

4. Preserved sites for professional education

Even in "empty" areas, the geological heritage is threatened, if only because of the eagerness of people nowadays to visit wilderness areas. It is therefore fortunate that the geological heritage now becomes more and more an object of preservation attention, though often not as a specific abiotic preservation, but rather as part of an integrated environmental entity. One should encourage this development, as geological features often owe their characteristics to biological influences, whereas the geology of an area, in turn, largely determines the local fauna and flora. In fact, the integration should lead to conditions that are as natural as possible (cf. Chamley, 2003). Integrated preserves can therefore well contribute to a better understanding of the endless interplay between the biotic and the abiotic nature, thus also providing a wider context for geological features.

The fortunate development of integrated preserves does not imply, however, that geological field education is no longer under threat. Earth-science education cannot be implemented at a sufficiently high level if the features to be studied do not include more specialized items than those that are to be expected in sites that are aimed at the preservation of integrated systems. It remains therefore unavoidable that, apart from more general preserves, specific earth-scientific preserves are established. Particularly in densely populated areas where already many valuable geological features have been destroyed or are no longer accessible, as well as in areas where the threat of a growing population and/or increasing prosperity – with all their consequences – exists, little time should be lost in the battle against definite destruction of not only our geological heritage, but also of the possibility to provide future generations of earth-science students with adequate field experience. Geological authorities such as state geological surveys and/or professional geological societies should even discuss the desirability of urging the national authorities to proclaim earth-science reserves for professional education. In such preserves – or at least in part of them – the general public should not have access, just like the public is not allowed to enter specific areas because of the presence of rare plants or because wildlife must have a refuge where it is not disturbed.

5. Survival of the earth sciences

In some countries it has always been difficult to provide students with adequate field experience. In The Netherlands, for instance, where hardly any sediments older than Quaternary outcrop, it has from the very beginning been custom to carry out fieldwork abroad (originally commonly in the previous colonies, later mostly in Spain and Scandinavia), and to have geological excursions in not too remote countries (Belgium, Germany, Great Britain, the Alpine countries). This becomes increasingly difficult, however. Many countries become confronted with a lack of areas for field practice of their own students, so that it becomes increasingly difficult to obtain permission for carrying out fieldwork in such countries; a result is that often less suitable areas must be used. Excursions pose also problems. The Ardennes always offered interesting excursion points, mostly in the form of small quarries. Small-sized quarries are no longer economically viable, however, so that they have been closed and vegetated. Large quarries do no longer grant access because of the legislative implications mentioned before.

One might think that The Netherlands are an exception because of the small size. Much larger countries face the same problems, however. Even a huge country like Poland has insufficient possibilities for mapping exercises of students, apart from the Tatra mountains which are, however, too complicated to train inexperienced students. And also Poland, which only recently joined the European Union and still can be considered as a country in a fairly early stage of development and industrialisation, has a great lack of hard-rock excursion points. It is therefore very fortunate that also Poland has already understood the necessity to establish earth-science preserves. Thus, at least some spectacular excursion points (Fig. 7) are saved for future generations.

Even in countries where a lack of field areas or excursion points seems far from realistic now, one should keep in mind that it took only a few decades – if not less – for several countries to lose an overwhelming number of areas and points that were valuable for earth-science education. And areas that have gone lost, will not come back. One should therefore certainly take measures before the problem becomes urgent.

It might be argued that there will always be areas where fieldwork can be carried out and where wonderful points for excursions will not disappear. The U.S. National Parks will certainly remain intact for a long time, if not forever, and they offer almost everything that earth-science education needs. One should realize, however, that one cannot take it for granted that these parks will allow future generations of students to study the interesting sites in these parks *en masse*, as the risk of destruction may become too large. Moreover, if such sites would become some kind of excursion points (or areas of field practice), students from other countries might be willing to go there, too. Obviously, it would not be realistic to assume that the US. National Park Service would allow students from all over the world to profit from the measures that the U.S. have taken to preserve the American geological heritage. All countries should take care of their own heritage, as far as reasonably possible.

Fig. 7. Giant bent gypsum crystals (Jurassic) in a wall beneath the church of Chotel Czerwony (Poland). The site has been appointed a status of preserve.

Another point of consideration is that travelling over large distances may become limited in the future. If this would not be for environmental reasons (pollution by cars and planes), it will be for financial reasons: Europe is working hard on a system where people have to pay for each kilometre that they drive by car, and several forms of airplane-taxes have already been introduced. Travelling far for visiting fieldwork areas or for excursions may therefore well become out of reach, particularly considering the decreasing funds that universities (can) spend on such activities.

The conclusion must be that the future of geology will change. Practical fieldwork and excursions will not be what they were in the past, when changing natural and human activities made exposures disappear and other sites becoming exposed. It seems that future generations of earth-science students will increasingly become confronted with "standard" excursion points and field practice, which will certainly limit the overall field experience. It may thus happen that geology becomes a science where the great diversity of the various features can no longer be observed in practice, but where the diverging forms of geological features will have to be deduced from videos and the application of comparable techniques. In this way, the earth sciences will become more like the other natural sciences: it has to be learned from textbooks, rather than from practice.

Even this future – which in my opinion is very unfortunate – can, however, not be taken for granted. Even "standard" excursions and field practice at purposely preserved sites can only be realized if such sites will have been appointed a status of preserve in time. Considering how quickly valuable sites get lost nowadays, one must be afraid that it is too late already to save all sites that deserve preservation. It is an additional reason why geologists should start immediately joint action to save our geological heritage. Otherwise there may not even be a future for geology at all.

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