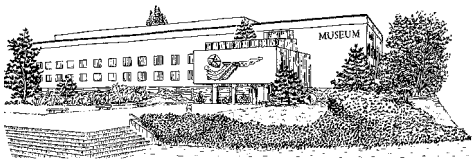
REVUE DE PALÉOBIOLOGIE

ISSN 0253-6730

VOL. 23, N°2 - 2004



Muséum d'Histoire Naturelle • Ville de Genève • Suisse

Revue de Paléobiologie, *Genève* (2004) Vol. spéc. 9 : 39-49 ISSN 0253-6730

The protection, conservation and sustainable use of the Courtedoux dinosaur tracksite, Canton Jura, Switzerland

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Abstract
In February 2002, a new dinosaur tracksite was discovered on public land on the future course of the "Transjurane" highway in Courtedoux, Canton Jura northwestern Switzerland. The Courtedoux tracksite is a "multithematical" geotope (Jordan, 2002a), with an extraordinary scientific potential and it has the potential for development into one of world's largest and most important sauropod tracksites (Lockley, 2002). Since its discovery, the protection and the conservation of the site *in situ* was promoted by the "Section de paléontologie". Simultaneously, the high level of scientific, media and public interest has proven the great scientific and educational value and the great potential for sustainable touristic use of the site. According to Swiss law, the site is a natural object of high scientific value and has to be protected from destruction, as, in Switzerland, heritage sites of national value are rated with the same level of significance as federal infrastructure projects, such as highways. Due to the favourable location of the site at one end of a viaduct, the site could be protected by the construction of an additional small highway-bridge. Such a building could provide ideal conditions for the conservation, scientific research and public viewing of the site.

Key words
Dinosaur, tracksite, sauropoda, Canton Jura, Transjurane, palaeontological heritage, natural monument, geotope, geopark, geotourism.

Résumé
La protection, la conservation et l'utilisation durable du site à traces de dinosaures de Courtedoux, canton du Jura, Suisse.- Au mois de février 2000, un nouveau site à traces de dinosaures a été découvert en terrain publique sur le tracé de l'autoroute Transjurane à Courtedoux dans le canton du Jura, nord-ouest de la Suisse. Le site de Courtedoux est un géotope « multithématique » (Jordan, 2002a) de grand intérêt scientifique qui a le potentiel pour se développer en l'un des plus grands et des plus importants sites à traces de sauropodes au monde (Lockley, 2002). Depuis sa découverte, la protection et la conservation du site sur place ont été effectuées par la Section de paléontologie. Dans le même temps, le grand intérêt montré par les milieux scientifiques et médiatiques, ainsi que par le public, a souligné la valeur scientifique et éducative du site : il possède un fort potentiel pour un développement touristique effectué de façon durable. Selon la législation suisse en vigueur, le site est considéré comme un objet naturel à haute valeur scientifique. En Suisse, les sites de valeur patrimoniale nationale sont considérés à un même niveau que les infrastructures fédérales telles que les autoroutes et doivent être protégés sur place. Le site à traces de dinosaures de Courtedoux, localisé favorablement à l'extrémité d'un viaduc, pourrait aisément être protégé par le biais de la construction d'un pont spécialement conçu. Un tel aménagement procurerait des conditions idéales pour la protection et la conservation, la poursuite des rechercherches scientifiques, ainsi que pour les visites publiques.

Mots-clés
Dinosaure, site à traces, sauropoda, canton du Jura, Transjurane, patrimoine paléontologique, monument naturel, géotope, géoparc, géotourisme.

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INTRODUCTION

The only record of the history of life lies in the rocks beneath our feet: they are the memory of the earth and they enable us to unravel the past. The palaeontological record is unique and often surprisingly fragile. What is lost can never be recovered and the conservation of our common palaeontological heritage for study for future generations of scientists as well as for the general public is evident.

The importance of the palaeontological heritage has been recognized in Canton Jura and, as a result of the construction of the "Transjurane" highway, a new palaeontological project, the "Section de paléontologie" was established in February 2000, which was engaged to save and examine the palaeontological heritage of the future highway course in the Canton Jura, northwestern Switzerland (THÜRING & HUG, 2001; MARTY *et al.*, 2002a). The project is financed by the Swiss Federal Roads Authority (95%) and the Canton Jura (5%). Similar archaeological survey projects have been common for a long time, but this is the first instance in which palaeontological heritage has found a similar acceptance in Switzerland.

In 2002 a new dinosaur tracksite of major importance for Switzerland's palaeontological heritage, was discovered in Courtedoux on the future course of the new highway. This paper deals with the palaeontological excavations of the Courtedoux site, the concept of geotopes and geoparks, the scientific and educational value of the tracksite, and its touristic potential.

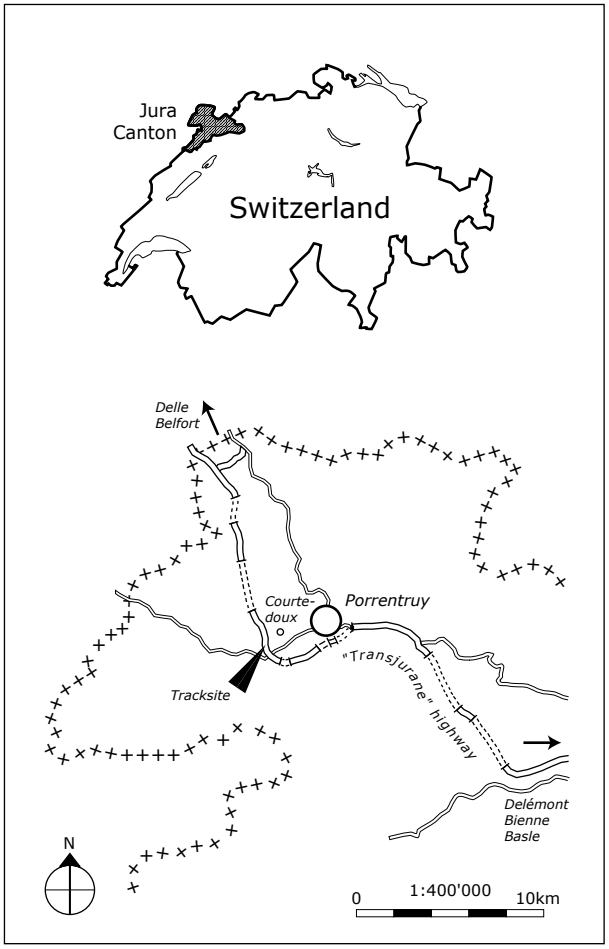
GEOGRAPHICAL AND GEOLOGICAL SETTING

The Courtedoux tracksite is situated in Canton Jura in northwestern Switzerland, in the so-called Ajoie region, about 5 km to the west of the city of Porrentruy on the future course of the "Transjurane" highway (Fig. 1).

Geologically, most of the Ajoie region is part of the tabular Jura Mountains (SCHNEIDER, 1960) and the main geological features of the region, which can also be observed on the tracksite, are normal faults (Fig. 3) associated with the rifting of the Rhine Graben and the folding of the Jura Mountains.

At the Courtedoux site, bedding is sub-horizontal and excavations are carried out in a cross-section with a total thickness of about 10 metres. The section is located between the Banné Member (GYGI, 2000) and the Marnes à *virgula* of the Reuchenette Formation (Upper Kimmeridgian). It starts with track-bearing laminites (about 1 metre), which have been deposited in an intertidal to supratidal environment. Fossiliferous marine limestones, marly limestones and calcareous marls follow in sequence, and the top of the section is marked by the Marnes à *virgula*. The whole section can be well dated with ammonites, which have been found in 5 different layers so far (MARTY *et al.*, 2003).

Fig. 1: Location of the tracksite and the "Transjurane" highway in the Canton Jura, northwestern Switzerland.

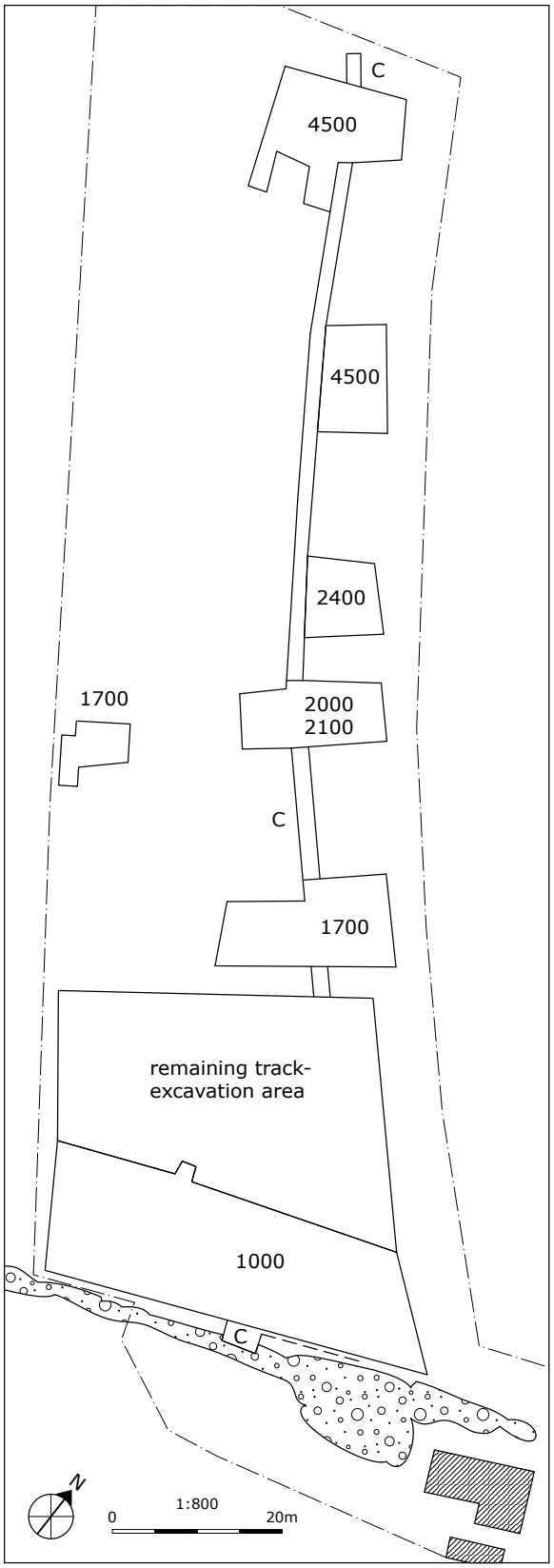


DISCOVERY AND EXCAVATION

Dinosaur tracks were first discovered in February 2002, during archeological and palaeontological prospecting along the future course of the "Transjurane" highway (MARTY *et al.*, 2002b). The tracks were found in a massive limestone at the base of calcareous laminites. To estimate the importance of the site, about 50 square metres were uncovered in the first phase of study. As the tracks were well preserved and also formed trackways, it was decided to excavate them over the largest possible area.

Excavations started in May 2002. Level 1000 (the lowermost track-bearing level) was carefully excavated with hand-tools over a surface area of about 650 square metres: the total track-excavation site covers approximately 1500 square metres (Fig. 2). This was also an area in which the overlying, potential track-bearing laminites have been strongly altered and could not have been excavated (MARTY *et al.*, 2002a). During the excavation phase, further tracks were recorded from another 5 levels and vertebrate remains (turtles, crocodiles and fishes) were found in one layer within the overlying calcareous laminites and in layer 1200.

Fig. 2: Excavation area of the Courtedoux site. The excavation areas are shown, and the numbers stand for the layers that have been excavated. Tracks have so far only been uncovered on level 1000. "c" stands for the cross-section, which connects all excavated layers.



Above the track-excavation area, different layers of marine marls (layer 2100, 4500 = Marnes à *virgula*) and limestones (layers 1200, 1700, 2000) were excavated systematically from June to December 2002, and a large sample of invertebrates and vertebrate remains were recovered from these layers.

Future excavations

At the Courtedoux site, at least 6 track-bearing levels with the potential to reveal valuable data, and two layers with vertebrate remains, can still be excavated in the remaining excavation area (about 900 square metres, Fig. 2). Moreover, the track-bearing laminites are also found beside this area. However, the "Section de paléontologie" undertakes excavations only along the future course of the highway. Nevertheless, as the site could be enlarged at a later time, this area should be protected from any later construction that might take place beside the highway. A richly fossiliferous marine section of about 9 metres thickness lies above the laminites, of which a few layers have, so far, been excavated.

To fully validate the site and to obtain maximum information, the Courtedoux site will be excavated as much as possible, to see what other track-data and body-fossils are available. In the fossiliferous marine layers fossils are dug up. However, it is evident that the excavation of the track-bearing levels, which lie one on top of each other, is a more delicate process, as it is not possible to expose all levels simultaneously. Once the uppermost level has been uncovered, it has to be removed to uncover lower levels. However, overlying layers should be removed and destroyed only if body fossils have been excavated and no significant tracks or trackways are found. Otherwise tracks and trackways should be preserved *in situ* and/or excavated or moulded for museum preservation, before continuing down to lower levels. Given that the overlying layers are generally made of less resistant rock than the area of level 1000 uncovered to date, it is anticipated that they will not withstand to exposure and weathering for as long as the main surface. Thus, one might hope to work down through these layers documenting, replicating and excavating tracks and trackways until the main surface is reached. This would have the dual benefit of obtaining all possible information by exposing more of the main layer. The possibility always exists of finding an important level before reaching the lowest one, and in such a case it may be desirable to preserve this level *in situ*.

In order to make the best decisions, the "Section de paléontologie" is currently working on an excavation concept that will check all possible excavation scenarios. The possibility of excavating whole levels, and putting them together beside the tracksite in an especially constructed shed will be considered.

Fig. 3 : Overview of the Courtedoux tracksite. Educational trail with visitor platform for scale. Note the well developped epikarstification along normal faults.

RESEARCH

Research at the Courtedoux site has been conceived and implemented from the beginning of the excavations and it is carried out by the "Section de paléontologie" in collaboration with national and international specialists. Given the size of the site, significant track-data is available and will continue to be obtained in the future. The uncovered area of level 1000 so far exhibits over 650 sauropod and theropod tracks, of which about 400 can be resolved into 17 sauropod trackways referrable to *Parabrontopodus* (Lockley *et al.*, 1994a ; Lockley & Meyer, 2000) and 2 trackways of theropod dinosaurs (Fig. 4). The sauropod trackway pattern reveals evidence for local shoreline-controlled travel by several groups of sauropods. More detailed research results are discussed in Marty *et al.* (2003).

In addition to the very extensive track-data, a significant amount of invertebrates (sea urchins, bivalves, gastropods, cephalopods) and vertebrate remains (turtles, crocodiles, sharks and bony fishes) have been and will continue to be acquired, allowing the site to be placed in the full context of the Late Jurassic fauna and environment, and into biostratigraphic context. Thus, the Courtedoux site is not only an important dinosaur tracksite, but also an important palaeontological site in a broader sense.

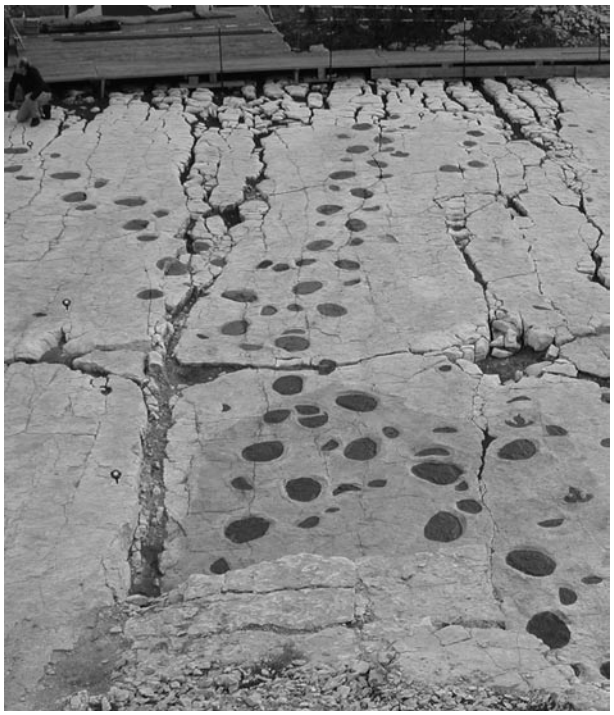
DISCUSSION

The building of the highway at Courtedoux demands immediate conservation efforts and the search for a sustainable solution for its long-term protection and accessibility. As the conservation of an outcrop is a legal rather than a scientific matter, this section outlines the official protection process. First, the legal background and the concept of geotopes and geoparks are highlighted. Second, the scientific, cultural, educational and tourist value of the site and possibilities of a future valorization are discussed.

The concept of geotopes and the actual legal situation of conservation

The geotope terminology was coined following an extension of an idea in conservation biology. An

Fig. 4: Crossroads of three sauropod trackways. On the right two tridactyl theropod tracks can be recognised. Note that tracks have been colored with emulsion paint. Man upper left for scale.



object of unique and outstanding appearance within a biological assemblage that contrasts with its surrounding is described as a biotope. Stürm (1993, 1994a) began to introduce the term geotope in Europe as a distinct part of the geosphere of outstanding geological and geomorphological interest. Some authors (e.g. Komoo, 1998) distinguish between the classical monothematic concept of geological heritage conservation and the new geotope concept, which aims to present a particular resource to the public as a heritage site, including aspects of the promotion and management of the site. The term geosite has been proposed (Wimbledon, 1996), which is more general in scope than geotope and encompasses any site that contains significant geological diversity.

In Switzerland, where the activities of geological heritage conservation nearly vanished in the 1960s, the term geotope was introduced to replace the out of date term "natural monument", which was restricted to abiotic sites, since the term biotope was introduced to the Federal Act on Nature and Heritage Conservation (Nature and Heritage Conservation Act) (NHG[1]). A working group of the Swiss Academy of Science, aiming for a renaissance and popularisation of geoconservation in Switzerland, elaborated the following definition (Strasser *et al.*, 1995): *Geotopes are geologically or geomorphologically valuable and sensitive parts of the countryside. They have to be protected against interventions, which could damage their substance, form or natural development. Geotopes are spatially restricted parts of the geosphere with a particular geological, geomorphological or geoecological importance. They contain important witness of earth's history and give insight in the development of the countryside and the climate. Static and active geotopes are distinguished.* I.e., neither the thematic diversity nor the (planed) promotion of a site to a broader public should be distinctive whether a site is a geotope or not. In their strategic paper, the working group lobbied for the need for implementation of the term geotope – parallel to biotope – into Federal Law. Stürm (1994b) notes that the concept of geotopes not only has to be introduced to the Federal Act on Nature and Heritage Conservation, but also to the Federal Act on Spatial Planning (Spatial Planning Act) (RPG[2]).

In 1999, the working group suggested a concept of geotope classification and introduced an informal inventory of 400 geotopes thought to be of national significance (Working Group for the Protection of Geotopes in Switzerland, 1999). Though, in Switzerland, the cultural and natural heritage conservation is mainly concentrated at State (Canton) level, the Federal Government takes a leading role in the introduction of new concepts. As a consequence of the publication of the Inventory of Geotopes of National Significance (Working Group for the Protection of Geotopes in Switzerland, 1999) and the lobbying of the working group, a task group of the Federal Office for Environment, Forest and Landscape (BUWAL), presented (in 2000) a concept for the survey and classification of geotopes of national significance. According to existing law on cultural and biological conservation, it was proposed to distinguish between sites of local, regional and national significance. A site may also be further classified as of scientific, educational, cultural or tourist value. The classification of a site is influenced by its actual state but not by susceptility to damage. An actual or future endangerment is, in relation to the significance of a site, decisive for the measurements taken for its protection and conservation.

Unfortunately, these recommendations have not yet been put into force. As the highway construction endangering the Courtedoux site is a national project, realized with Federal money and performed under the auspices of the Federal Government, a federal Guideline would be necessary, to classify and protect the Courtedoux site.

[1] NHG: Bundesgesetz über Natur und Heimatschutz, Federal Act on Nature and Heritage Conservation (Nature and Heritage Conservation Act), Loi fédérale sur la protection de la nature et du paysage (LPN).

[2] RPG: Bundesgesetz über die Raumplanun, Federal Act on Spatial Planning (Spatial Planning Act), Loi sur l'aménagement du territoire (LAT).

Thus the legal situation in combination with the informal classification scheme for geotopes has to be taken in account (JORDAN, 1999). According to the Swiss Civil Code (ZGB[3] Art. 724), the State (the Canton Jura in the present case) on whose territory objects of scientific value are found, is owner of these objects, and is responsible for its protection (ZGB Art. 702). Also, the Swiss Civil Code (ZGB Art 641) states that it is not lawful, to destroy the property of others. Consequently, in the present case, the Federal Government, which initiated the construction of the highway, has to take all measurements, to protect the property of the Canton Jura. Additionally, in the case of a high risk of destruction, different laws apply for a "short term" protection (ZGB Art.702, RPG Art. 37 and NHG Art.15f). In the domain of archaeology, this interpretation has applied for a long time with respect to highway constructions (MEYER & JORDAN, 2001). However, in the case of archaeological findings, the site is usually mapped, and all objects are then removed. The concept of conserving a site *in situ* and guaranteeing of future accessibility was not yet realized in the case of threats from Swiss highway construction.

The concept of geoparks

A geopark is a territory encompassing one or more sites of scientific importance, not only for geological reasons, but also by virtue of its archaeological, ecological or cultural value. The geological heritage has to be safeguarded and sustainably managed. However the management plan should also meet the economic needs of the local population whilst safeguarding the geological heritage and the landscape in which they live (EDER, 2002). Thus, a geopark has both a conservation and an economic aspect, of which geotourism is the most prominent part. European geotourism, both educational and recreational, has roots in Austria (HOFMANN & SCHÖNLAUB, 1994) and has become very popular recently. More than a dozen of geoparks, located from Greece to Ireland, are now organized in the European Geoparks Network, which has created labels and trademarks to set standards and to guarantee a high quality geoparks. In Switzerland, two geoparks are already established (JORDAN, 2002b). Geoparks and geotourism in a wider sense are becoming more important in regional green- or eco-tourism concepts that might create employment and provide sustainable economic development, especially in rural environments (JORDAN *et al.*, 2002).

However, the establishment of a geopark requires collaboration between scientists, tourism-specialists, businesses and private interests from the region in order to work out a high quality management plan (JORDAN *et al.,* 2002). Most of the established geoparks benefit from government or European Union support dessignated for remote and developing areas or cultural efforts. Close collaboration with the Network of European Geoparks, and UNESCO, which supports national geopark efforts, has recently created standards for the creation of geoparks (EDER, 2002).

Tracksites as geotopes

Fossil footprint sites are particularly significant as not only are they part of the ancient landscape, but they are also part of the present landscape (LOCKLEY & MEYER, 1997 ; JORDAN, 1999). In most parts of the world, fossil footprint sites are considered an important part of natural heritage and have become integral parts of the cultural heritage in the regions where they are located (LOCKLEY & MEYER, 1997). As they are normally very large sites, they can only be preserved *in situ*. Erosion or natural weathering is the main danger threatening a tracksite and if no protection (by a roof or other adequate structure) is provided, it will eventually be destroyed (WINKLER, 1987). Protection against weathering is thus the most important part of the conservation process. Once a site is protected, it has to be maintained to prevent covering by vegetation. As such an outdoor protection is expensive, most of the protected tracksites are also made accessible to the public and used as tourist attractions in geoparks or dinosaur-parks.

In Switzerland, the Lommiswil tracksite (MEYER, 1990) was the first geotope to be protected officially and an observation platform with notice boards has been installed (BERGER, 1999).

In Europe, sites such as Münchehagen (FISCHER, 1998) and Barkhausen, Germany (KAEVER & LAPPARENT, 1974), "La Ruta de las Icnitas" ("the route of trackways") in La Rioja, Spain (MORATALLA, 1993 ; MORATALLA *et al.*, 1997), and Fatima (SANTOS *et. al.,* 1994) and Carenque (SANTOS *et al.*, 1992) in Portugal all represent similar developments around fossil footprints. The Barkhausen and Münchehagen sites have been protected under especially constructed sheds and the latter is today the center of a dinosaur park (Dinosaurierpark Münchehagen). In Portugal at least five national monuments have been created in the last decade around important tracksites. The most spectacular is the Carenque tracksite, in the suburbs of Lisbon, where a tracksite was found in the path of a freeway development (SANTOS *et al.,* 1992 ; GALOPIM DE CARVALHO, 1994). The Portuguese government and president intervened to divert the freeway through two tunnels beneath the tracksite, at a cost of about 8'000'000 $US (early 1990s value).

In the USA, several parks (Dinosaur Ridge, Dinosaur State Park, Dinosaur Valley State Park) have been set aside to preserve and display vertebrate footprints. Dinosaur Valley State Park and Dinosaur Ridge,

[3] ZGB : Zivilgesetzbuch, Swiss Civil Code, Code Civil.

Colorado (built around a dinosaur tracksite) receive tens to hundreds of thousands of visitors each year. Similar sites and visitation figures can be cited for localities in Texas and Utah. This tourist development has taken place only in the last ten years (Hayden *et al*., 2001 ; Lockley & Taylor, 2001, Kirkland *et al.,* 2002).
In China, several tracksites are under consideration for inclusion in the UNESCO's International Network of Geoparks programme and, in Japan, a tracksite at Sebayashi provided the impetus for the development of the "Nakasato Dinsoaur Center". In Queensland, Australia, the Lark Quarry site (Thulborn & Wade, 1984) is accesible to the public and has been protected from normal processes of erosion by a roof (Agnew *et al.,* 1989).

Analyzing the value of the Courtedoux site

Generally the significance of a palaeontologically important site can be measured in terms of uniqueness (even if in one sense any site is unique) or representativeness (shown in this paper by a comparison with other similar sites), scientific and educational value, management and accessibility. It can be classed as important at local, regional, national, international or world heritage level. The scientific significance of a site is based mainly on its documented description (Joyce, 1994).

Comparison with other sauropod tracksites

It should be noted, that from a scientific perspective, a simple comparison of tracksites in terms of raw numbers might not be appropriate. Nonetheless, the number of trackways is important for statistical studies and for the study of sauropod palaeoecology and it might be a good indication of the overall importance of a sauropod tracksite, even if there are other factors (track preservation, track size variation, length of trackways, evidence for special behaviour, etc.) that one should also consider to determine the importance of a particular site. The following comparison (Fig. 5) is therefore necessary to place the Courtedoux site in its global context.
In Switzerland, more than 20 Late Jurassic dinosaur tracksites are known so far (Meyer, 1993 ; Meyer & Lockley, 1996 ; Meyer, 1997 ; 2000 ; Ayer, 2001 ; Meyer & Thüring, 2003). However, most of these sites are very small and only Lommiswil and Moutier can be considered large sites. Moreover, only the Lommiswil site shows clear sauropod trackways, numbering a maximum of nine of which several are short and indistinct segments (Meyer, 1990 ; 1993). Thus, the Courtedoux site reveals more trackways than previously known at any other Swiss site.
The Courtedoux site also compares very favorably with all other regions in Europe. Sauropod tracksites are found in many European countries including France (Lockley & Meyer, 2000), Croatia (Mezga *et al.,* 2003), Poland (Gierlinski, 1997 ; Gierlinski & Sawicki, 1998),

Fig. 5 : Large, documented (mapped), single-surface, sauropod tracksites in rank order of trackways abundance. The Courtedoux site is in the sixt place of the sites with most sauropod trackways (in terms of raw numbers) worldwide and in the third place within the Jurassic.

Tracksite	Location	Age	Sauropod trackways	Other trackways
Cal Orcko	Bolivia	Late Cretaceous	143	187
Purgatoire River	Colorado, USA	Late Jurassic	about 40	about 60
Ardley Quarry	England, GB	Middle Jurassic	39	3
Fumanya	Spain	Late Cretaceous	26	0
Davenport Ranch	Texas, USA	Early Cretaceous	23	5
Courtedoux	Switzerland	Late Jurassic	17	2
Cabo Espichel	Portugal	Late Jurassic	12	1
Lommiswil	Switzerland	Late Jurassic	9	0
Barkhausen	Germany	Cretaceous	7	2
Alvelino	Portugal	Middle Jurassic	5	0

England, Spain, Portugal and Germany. Tracksites with several sauropod trackways on a single surface are found in England, Spain, Portugal and Germany. The Ardley Quarry (Oxfordshire) in England exhibits 39 sauropod trackways (Day *et al.,* 2002, 2004), the Fumanya site in Spain at least 26 (Schulp & Brokx, 1999), Cabo Espichel in Portugal 12 (Lockley *et al.,* 1994b), and Barkausen in Germany 7 (Kaever & Lapparent, 1974) trackways of sauropods on the same horizon.

The only other regions of the world, where sauropod trackways are abundant, and reasonably well documented are Bolivia, the Western United States, and South Korea (Lim *et al.,* 1989, 1994). The site with most sauropod trackways on a single surface is the Cal Orcko site near Sucre, Bolivia, where 143 titanosaurid trackways and 187 other trackways (of theropods, ornithopods and ankylosaurs) have been reported so far (Meyer *et al.,* 2001; Lockley *et al.,* 2002). In the USA, about 40 sauropod and 60 theropod trackways are associated with the main level at the Purgatoire tracksite in Colorado (Lockley, 1997) and at Davenport Ranch in Texas, 23 trackways of sauropods heading in one direction can be observed over a relatively narrow section (Bird, 1944; Lockley & Hunt, 1995). However, the latter site is much smaller than the Courtedoux site and trackways are overprinting each other.

Scientific value

Dinosaur palaeontology is popular and the need to acquire reliable data for publication in scientific journals and comparisons with other sites is significant. Moreover, scientific documentation and research is the base for the palaeontological valorisation of a site and thus for public attraction and media documentaries. Public interest might stimulate future research.

At the Courtedoux site, the potential for expanding the excavations is very high, and would be low cost, thanks to the shallow disposition of the track-bearing and fossiliferous layers in near horizontal strata. The calcareous laminites represent an enormous track-data resource, and the overlying marine layers provide the palaeoecological and biostratigraphical context with a great potential for new finds of excellent invertebrate and vertebrate fossils. Beside palaeontological excavations, the site also offers many possibilities for studies in sedimentology, sequence stratigraphy, hydrogeology, structural geology, geophysics or geomorphology.

Educational and economic (touristic) value

Imparting of palaeontological and geological knowledge in the field is always more effective and interesting than in school. As the Courtedoux site is a multithematical geotope (Jordan, 2002a), the above mentioned interactive network of the geosciences can be explained at its best. The site thus has tremendous educational and pedagogic value.

The Courtedoux tracksite has stimulated a high level of scientific, public and media interest and an educational trail to the site has been installed, allowing visits (Fig. 3). In just a few months in 2002, more than 10'000 tourists from Switzerland, France and Germany visited the site (Fig. 6). A constructive, ongoing relationship has been established with the region's inhabitants and many people have been sensitized to the value of palaeontological and geological research. At the same time, no conflicts between preservation and use have been observed during this intensive period of visits. The site is very easily accessible (instant highway access) and provides excellent opportunities for public viewing without risk of damage through overuse (Fig. 6), which is quite unlike the problems encountered at many other steeply inclined sites in mountainous terrain. Due to the favourable location of the site at one end of a viaduct, the site could be protected by the construction of an additional small highway-bridge on total surface area of approximately 1500 square metres. Such a building could provide ideal protection, conservation and public presentation (by installing trails and special illumination) of the tracksite, if the site developes in coordination with the future construction of the highway-bridge. In that case, the site has an excellent potential for development as an interpretive center with an associated museum, shop and restaurant. Such an interpretive center could figure as a locality for carrying out exhibitions and courses, and as a meeting point for guided tours. It might even act as a magnet for regional tourism and become the main attraction of a future Jura Geopark (see below). However, to develop such an infrastructure, the site needs a high quality site management plan – an administrative and management challenge for both scientists and cantonal authorities – which still has to be elaborated.

Possibilities for a future Jura Geopark

The Jura Mountains have a huge number of other interesting and attractive geotopes (Baechler *et al.*, 2003), which could easily be combined in a Jura Geopark (Berger, 2003; Marty & Hug, 2003). The most important geotopes are listed in the "Inventory of Geotopes of National Significance" (Working Group for the Protection of Geotopes in Switzerland, 1999).

CONCLUSIONS

The Courtedoux site is an outstanding sauropod tracksite of international importance and it provides a great opportunity for the future development of palaeontology in the Canton Jura and Switzerland, as the excavations

Fig. 6 : A school class on the Courtedoux site during the visiting days.

offer a great potential for new finds and research can still be carried out for many years to come.

The site was recently included in the informal list of the Swiss Academy working group for geotopes. Following the classification scheme proposed by the BUWAL task force in 2000, the Courtedoux site is a "multithematic" geotope of national value (Jordan, 2000a). The rating is not only based on its outstanding scientific significance but also on its educational and cultural value and, last but not least, tourist (economic) potential. The site also matches the definitions of an important geotope or geosite according to Wimbledon (1996) and Komoo (1998). Beyond, a European significance (a classification not established as yet) is suggested, and it is belived that the site might probably match World Heritage standards (e.g. Grube, 1993), if further excavations are carried on.

The public's interest in tangible reminders of the dinosaurs has been clearly demonstrated during the visiting days. A public relations exercise carried out at the Courtedoux site showed that scientific research results, explained to the mass media, can establish a constructive and stable relationship with the region's inhabitants and quickly sensitize them to their palaeontological heritage. This process of public sensitization or education by scientists is the first and most important step towards the protection of any palaeontological site (Bernier *et al.,* 1994 ; Berger, 1999 ; Lockley, 2001), because only once the public understands the importance of the palaeontological heritage can protection and conservation be possible.

The Courtedoux site, as a non-renewable resource on public land, has proven its excellent scientific, educational and tourism potential. It offers the possibility of combining scientific study of palaeontology and geology with a didactic and cultural purpose. It is easily accessible and has excellent opportunities for public viewing. These combinations of factors make the site superior in comparison with other similar sites in Switzerland. If the site will be protected by a highway-bridge, many of opportunities (development as an interpretive center, museum, etc.) for scientific and geotouristic use might arise and the site could figure as the main attraction of a future Jura Geopark, which, integrated into a regional green- or eco-tourism concept, may create and safeguard jobs and provide sustainable economic development in a rural area.

ACKNOWLEDGEMENTS

The "Section de paléontologie" would like to thank the Swiss Federal Roads Authority (FEDRO) and the Canton Jura who finance the project.

We thank Pierre-Alain Borgeaud and his team ("équipe de sondage de la Section d'archéologie et paléontologie du Canton du Jura") who originally found the tracksite and all technical staff of the "Section de paléontologie", who participated in the track-excavations.

For their ongoing good collaboration and their great interest in the Courtedoux site, we are grateful to the following technical and political authorities : Federal Roads Authority (FEDRO), ministers of the Canton Jura, deputies of the parliament of the Canton Jura, road construction office of the Canton Jura (Ponts et Chaussée), environmental protection office of the Canton Jura (OEPN), municipal councillors of Courtedoux and the chief engineer of the "Transjurane" highway of the Canton Jura (R. Bläuer).

Last but not least we thank our scientific collaborators, everybody who was interested in our work and all visitors of the Courtedoux site demonstrating the great community interest of the site.

Finally thanks to the reviewers Paul Barrett and Vanda Faria dos Santos for their comments, which helped to improve the manuscript.

REFERENCES

Agnew, N., H. Griffin, M. Wade, T. Tebble & W. Oxman (1989) - Strategies and techniques for the preservation of fossil tracksites. *In* : Gillette, D.D. & Lockley, M.G. (Eds). Dinosaur tracks and traces, *Cambridge University Press :* 397-407.

Ayer, J. & B. Claude (2001) - Découverte d'une piste de dinosaure sauropode dans le Kimméridgien de la Région de Bienne (Jura Central, Canton de Berne, Suisse). *Bulletin de la Société Neuchâteloise des Sciences Naturelles*, 124: 149-159.

Baechler, J., E. Robledo & J.-P. Berger (2003) - Geotopinventar des Kantons Jura : state of the art. Abstract, Geotop 2003, 19.-24.07.2003, Bad Ragaz, Switzerland, abstract volume : 55.

Berger, J.-P. (1999) - Géotopes et collectionneurs de fossiles : dangers et avantages. *Geol. Insubr.*, 4 (1) : 79-82.

BERGER, J.-P. (2003) - Jurassic Parc : Im Jura wo denn sonst ? Abstract, Geotop 2003, 19.-24.07.2003, Bad Ragaz, Switzerland, abstract volume : 17.

BERNIER, P., G. BARALE, J.-P. BOURSEAU, E. BUFFETAUT, C. GAILLARD, J.-C. GALL & S. WENZ (1994) - La médiatisation des fouilles paléoécologiques effectuées dans les calcaires lithographiques de Cerin (Jura méridional, France). Son rôle dans la protection du gisement. *Mém. Soc. géol. France*, 165 : 237-240.

BIRD. R.T. (1944) - Did Brontosaurus ever walk on land ? *Natural Histor*y, 53 : 61.

DAY, J.J., D.B. NORMAN, A.S. GALE, P. UPCHURCH & H.P. POWELL (2004) - A Middle Jurassic dinosaur trackway site from Oxfordshire, UK. *Palaeontology,* 47 (2): 319-348.

DAY, J.J., P. UPCHURCH, D.B. NORMAN, A.S. GALE & H.P. POWELL (2002) - Sauropod Trackways, Evolution, and Behavior. *Science*, 296 : p. 1659.

EDER, F.W. (2002) - Promotion of geological heritage through UNESCO. Abstract, Conf. natural and cultural landscape, the geological foundation, Dublin, 9-11. Sept. 2002.

FISCHER, R. (1998) - Das Naturdenkmal "Saurierfährten Münchehagen". *Mitt. geol. Inst. Univ. Hannover*, 37 : 125 p.

GALOPIM DE CARVALHO, A. M. (1994) - Dinossáurios e a batalha de Carenque. *Editorial Noticias,* Lisbon, Portugal, 291 p.

GIERLINSKI, G. (1997) - Sauropod tracks in the Early Jurassic of Poland. *Acta Palaeontologica Polonica*, 42(4) : 533-538.

GIERLISNKI, G. & G. SAWICKI (1998) - New sauropod tracks from the Lower Jurassic of Poland. *Geological Quarterly*, 42(4) : 477-480.

GRUBE, A. (1993) - Die « World Heritage List » der UNESCO. Geotopschutz, Naturschutz, Wasserschloss Mitwitz, Materialien, 1 : 25-27.

GYGI, R. A. (2000) - Annotated index of lithostratigraphic units currently used in the Upper Jurassic of northern Switzerland. *Eclogae geol. Helv.*, 93 : 125-146.

HAYDEN, M. C., J.I. Kirkland, S. JOHNSON, M.G. LOCKLEY & J.P. POLICELLI (2001) - A new dinosaur tracksite in St. George Utah provides opportunities for science education and community involvement. *Journal of Vertebrate Palaeontology*, 21 : 59A.

HOFMANN, T. & H.P. SCHÖNLAUB (1994) - Geotourismus als Bewusstseinserweiterung. *Geowissenschaften*, 12(5-6) : 174-177.

JORDAN, P. (1999) - Geotopschutz – die rechtliche Situation in der Schweiz. *Geol. Insubr.*, 4 (1) : 55-58.

JORDAN, P.J. (2002a) - Expertise zum Geotope Dinosaurier-Fundstelle « Sur Combe Ronde »/Courtedoux, JU. Expertise pour la Section de paléontologie, Office du patrimoine historique, Porrentruy, JU, 4 p.

JORDAN, P. (2002b) - Geotope, Geotopschutz und Geoparks in der Schweiz. *natur + mensch*, 2/2002 : 6-7.

JORDAN, P., D. IMPER & R. HIPP (2002) - Erdgeschichten – Geoparks als Instrument zum Schutz der Landschaft und zur Förderung der regionalen Wirtschaft. *tec 21*, 31/32 : 12-15.

JOYCE, E.B. (1994) - Assessing the significance of geological heritage sites : from the local level to world heritage. *Mém. Soc. géol. France*, 165 : 37-43.

KAEVER, M. & A.F. LAPPARENT (1974) - Les traces de pas de dinosaures du Jurassique de Barkhausen (Basse Saxe, Allemagne). *Bull. Soc. Géol. France*, 7 (16) : 516-525.

KIRKLAND, J. I., M.G. LOCKLEY & A.R. MILNER (2002) - The St. George dinosaur tracksite. *Utah Geological Survey Notes*, 34 : 4-5.

KOMOO, I. (1998) - Conservation Geology. *In* : MAZLAN, O. (Ed.). Sekalung Budi Setitis Tinta, Festschrift Buat Sham Sani Sempena Hari Jadi, Ke-55 : 43-52.

LIM, S.-K., M.G. LOCKLEY, S.-Y. YANG, R.F. FLEMING & K. HOUCK (1994) - A preliminary report on sauropod tracksites from the Cretaceous of Korea. *Gaia*, 10 : 109-117.

LIM, S.-K., S.-Y. YANG & M.G. LOCKLEY (1989) - Large Dinosaur Foorprint Assemblages from the Cretaceous Jindong Formation of Southern Korea. *In* : GILLETTE, D.D. & LOCKLEY. M.G. (eds). Dinosaur Tracks and Traces, *Cambridge Univ. Press,* Cambridge : 333-336.

LOCKLEY, M.G. (1997) - The Paleoecological and Paleoenvironmental Utility of Dinosaur Tracks. *In* : FARLOW, J.O. & BRETT-SURMANN, M.K. (eds). The Complete Dinosaur, *Indiana University Press*, 554-578.

LOCKLEY, M. G. (2001) - A Field Guide to Dinosaur Ridge. Published as : A joint project of the Friends of Dinosaur Ridge and University of Colorado at Denver Dinosaur Trackers Research Group, fully revised 3rd edition, 34 p.

LOCKLEY, M.G. (2002) - Report on the Significance of the Courtedoux Dinosaur Tracksite, near Porrentruy, Switzerland. Expertise pour la Section de paléontologie, Office du Patrimoine historique, Porrentruy, JU, 8 p.

LOCKLEY, M. G., J.O. FARLOW & C.A. MEYER (1994a) - *Brontopodus* and *Parabrontopodus* Ichnogen. nov. and the Significance of Wide- and Narrow-gauge Sauropod Trackways. *Gaia*, 10 : 135-146.

LOCKLEY, M.G & A.P. HUNT (1995) - Dinosaur Tracks and Other Fossil Footprints of the Western Unites States. *Columbia University Press,* New York, 338 p.

LOCKLEY, M.G. & C.A. MEYER (1997) - Sacred Ground : Walking in the Footsteps of our ancestors. *In :* HUH, M., S.S.Y. YANG, M.G. LOCKLEY & Y.N. LEE (eds). Proceedings of the International Dinosaur Symposium for the Uhangri Dinosaur Center and Theme Park. *Chonnam National University :* 211-220.

LOCKLEY, M.G. & C.A. MEYER (2000) - Dinosaur tracks and other fossil footprints of Europe. *Columbia University Press,* New York, 321 p.

LOCKLEY, M. G., C.A. MEYER & V.F. DOS SANTOS (1994b) - Trackway Evidence for a Herd of Juvenile Sauropods from the Late Jurassic of Portugal. *Gaia*, 10 : 27-36.

LOCKLEY, M.G., A.S. SCHULP, C.A. MEYER, G. LEONARDI & D. KERUMBA MAMAMI (2002) - Titanosaurid trackways from the Upper Cretaceous of Bolivia : evidence for large manus, wide-gauge locomotion and gregarious behaviour. *Cretaceous Research*, 23 (3) : 383-400.

LOCKLEY, M. G. & A. TAYLOR (2001) - Dinosaur Ridge : celebrating a decade of discovery. *Mountain Geologist*, 38(3) : 87-164.

MARTY D., L. CAVIN & W.A. HUG (2002a) - Preliminary report of the excavations at the Late Jurassic Courtedoux dinosaur tracksite carried out by the « Section de paléontologie » (Canton Jura, Northern Switzerland). Abstract, 3e Symposium « Georges Cuvier », Montbéliard.

MARTY, D., L. CAVIN, W.A. HUG, C.A. MEYER & M.G. LOCKLEY (2002b) - Preliminary report of a dinosaur trackway site in the Late Jurassic of Courtedoux, Northern Switzerland. Abstract, EPA Workshop on Freshwater & Brackish (Paleo) Ecosystems, Fribourg.

MARTY, D., L. CAVIN, W.A. HUG, C.A. MEYER, M.G. LOCKLEY & A. IBERG (2003) - Preliminary report of the new Courtedoux dinosaur tracksite from the Upper Kimmeridgian of Switzerland, *Ichnos,* 10 : 209-219.

MARTY, D. & W.A. HUG (2003) - Das Dinosaurier-Spurenvorkommen von Courtedoux, Kanton Jura : dauerhafter Geotopschutz und nachhaltige Nutzung. *In :* JORDAN, P., R. HEINZ, P. HEITZMANN, R. HIPP & D. IMPER (eds). Geotope - wie schützen/Geotope - wie nützen. *Schriftenreihe der Deutschen Geologischen Gesellschaft,* 31 : 115-121.

MEYER, C.A. (1990) - Sauropod tracks from the Upper Jurassic Reuchenette Formation (Kimmeridgian, Lommiswil, Kt. Solothurn) of Northern Switzerland. *Eclog. Geol. Helv.*, 82 (2) : 389-397.

MEYER, C.A. (1993) - A sauropod dinosaur megatracksite from the Late Jurassic of Northern Switzerland. *Ichnos*, 3 : 29-38.

MEYER, C.A. (1997) - Die grosse Spurenplatte in der Schlucht von Moutier. *Schweizer Strahler*. 11(4) : 142-146.

MEYER, C.A. (2000) - Ein Jura-Querschnitt von Solothurn bis Basel (Exkursion C1 und C2 am 27. und 28. April 2000). *Jber. Mitt. Oberrhein. Geol. Ver.*, 82 : 41-54.

MEYER, C.A. & M.G. LOCKLEY (1996) - The Late Jurassic continental record of Northern Switzerland – evidence and implications. *In :* MORALES, M. (ed.). The continental Jurassic. *Museum of Northern Arizona,* Flagstaff, 421-426.

MEYER, C.A., D. HIPPLER & M.G. LOCKLEY (2001) - The Late Cretaceous vertebrate ichnofacies of Bolivia – facts and implications. *Asociacion Paleontologica Argentina, Publication Especial,* 7 : 133-138.

MEYER, C.A. & P. JORDAN (2001) - Paläontologie als Kulturgut und Wege, dieses im Rahmen einer Grossbaustelle zu bergen. *In* : SCHMAEDECKE, M. & P. JORDAN (eds). Ein Schnitt durch den Jura – geologische und archäologische Aufschlüsse beim Bau der Transitgasleitung TRG 3. *Berichte aus Archäologie und Museum Baselland,* Liestal : 29-30.

MEYER, C.A. & B. THÜRING (2003) - Dinosaurs of Switzerland. *C.R. Paleovol*, 2 : 103-117.

MEZGA, A., Z. BAJRAKTAREVIC, B.C. TETOVIC & I. GUSIC (2003) - First record of the dinosaurs in the Late Jurassic sediments of Istria, Coratia (preliminary report). 1st Meeting of the European Association of Vertebrate Palaeontology, Basel, 15th-19th of July, Abstract Volume : 30.

MORATALLA, J.J. (1993) - Restos indirectos de dinosaurios del registro español : Paleoicnolgía de la Cuenca de Cameros (Jurásico superior-Cretácico inferior) y Paleoología del Cretácico superior. Thesis Doctoral, Univ. Autónoma de Madrid, Fac. Ciencias, 729 pp.

MORATALLA, J.J., J.L. SANZ & S. JIMENEZ (1997) - Dinosaurios en La Rioja. Guía de yacimientos paleoicnológicos. *Iberdrola y Gobierno de La Rioja*, 176.

SANTOS, V.F. DOS, M.G. LOCKLEY, C.A. MEYER, J. CARVALHO, A.M. GALOPIM DE CARVALHO & J.J. MORATALLA (1994) - A new sauropod tracksite from the Middle Jurassic of Portugal. *Gaia*, 10 : 5-14.

SANTOS, V.F. dos, M.G. LOCKLEY, J.J. MORATALLA & A.M. GALOPIM DE CARVALHO (1992) - The longest dinosaur trackway in the world? Interpretations of Cretaceous footprints from Carenque, near Lisboa, Portugal. *Gaia*, 5 : 18-27.

SCHNEIDER, A. (1960) - Geologie des Gebietes von Sigfriedblatt Porrentruy. Inauguraldissertation, University of Basel, 73 p.

SCHULP, A.S. & BROKX, W.A. (1999) - Maastrichtian Sauropod Footprints from the Fumanya Site, Berguedá, Spain. *Ichnos*, 6 (4) : 239-250.

STRASSER, A., J.-P. BERGER, D. DECROUEZ *et al.* (1995) - Geotope und der Schutz wissenschaftlicher Objekte in der Schweiz : ein Strategiebericht. Arbeitgruppe Geotopschutz Schweiz, 28 p.

STÜRM, B. (1993) - Geotop – Grundzüge der Begriffsentwicklung und Definition. *In* : Ökologische Bildungsstätte Oberfranken - Naturschutzzentrum Wasserschloss Mitwitz e.V. (Ed.). *Geotopschutz – Workshop « Geotopschutz und geowissenschaftlicher Naturschutz »*. Mitwitz, Materialband, 1/1993 : 13-14.

STÜRM, B. (1994a) - The geotope concept. *In* : O'HALLORAN, D., C. GREEN, M. HARLEY, M. STANLEY & J. KNILL (eds). Geological and Landscape Conservation. *Geological Society,* London : 27-31.

STÜRM, B. (1994b) - Intégration de la protection du patrimoine géologique dans l'aménagement du territoire en Suisse. *Mém. Soc. géol. France*, 165 : 93-97.

THULBORN, R.A. & M. WADE (1984) - Dinosaur trackways in the Winton Formation (Middle-Cretaceous) of Queensland. *Memoirs of Queensland Museum*, 21 : 413-517.

THÜRING, B. & W.A. HUG (2001) - The first official palaeontological survey in Switzerland Section de paléontologie. Abstract, Ninth Swiss Sed Meeting, Fribourg, abstract volume, p. 45.

WIMBLEDON, W.A.P. (1996) - GEOSITES – a new conservation initiative. *Episodes*, 19 (3) : 87-88.

WINKLER, E.M. (1987) - Weathering and weathering rates of natural stones. *Environm. Geol. and Water Sci.*, 9 (2) : 85-92.

WORKING GROUP FOR THE PROTECTION OF GEOTOPES IN SWITZERLAND, SAS/SANW/ASSN (1999) - Inventory of Geotopes of National Significance. *Geol. Insubr.*, 4 (1) : 31-48.