4.2. RESEARCH IN THE LABORATORY OF GEOMORPHOLOGY AND GEOLOGY OF THE QUATERNARY AT THE UNIVERSITY OF LIEGE

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4.2.1. Introduction**

Research conducted in this laboratory displays wide diversity. Selected examples featured below illustrate the range of work carried out. It is of course impossible to present in a few lines the exhaustive results obtained.

Investigations in the field of **periglacial geomorphology** (carried out by A. Pissart) involve present-day frigid zones (Arctic and mountainous régions), laboratory experiments and also periglacial fossil phenomena (example p. 109).

Karst research, carried out by, and under the direction of C. Ek, involves surface and subterranean morphology of karsts, the qualities of karst waters and also the CO^2 content of cavities (vide p. 110). Allied to this research is the **radiometric dating of speleothems by ^{14}C and U/Th**, undertaken by M. Gewelt (vide p.113).

Tephrostratigraphy in particular is a highly developed field in our laboratory thanks to research conducted by E. Juvigné involving, in the main, vulcanism in the Eifel and the Massif Central. He also made on-site studies of the distribution of tephra from El Chichon (Mexico) and Mount Saint Helens in order to account for mineralogical variation in the tephra identified in Western Europe in Quaternary formations (vide pp. 114).

Subareal and submarine **coastal morphology** in the western Mediterranean is studied in our laboratory by A. Ozer, who uses uplifted beaches as criteria, among others, in defining neotectonic deformations (vide pp. 116).

The study of ancient erosion surfaces and terraces carried out by A. Demoulin similarly enables **recent uplifting** on the northern edge of the Ardenne to be evidenced (vide p. 118).

Further, a **macroseismic map** produced by M. François after the Liège earth tremor in 1983 has provided evidence showing that these neotectonic movements connected with the Rhine graben carry through today as far as Liège (vide p. 120).

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** By A. Pissart.

The **weathering of rocks** resulting from alternate freezing/thawing and wetting/drying is studied by V. Hamès and A. Pissart (vide p. 122).
The study of **fluvial transport in suspension** and dissolution reveals the diversity of contributory factors and, as illustrated by the example on p. 123 demonstrates that transport in suspension has greatly increased in the Meuse since a hundred years ago subsequent upon diking of the river.
Geomorphological cartography of a topographical plate extending from the Condroz to the Ardenne is presently being carried out by F. Girolimetto (pp. 124) with especial attention to the significance of lineaments observed on aerial photographs and satellite pictures.
Various other research projects dealing, for example, with sedimentology (pebbel-count, study of ferro-titanic minerals, pollen-separation techniques); or with cartography of mounds resulting from Celtic gold-penning in the Ardenne; or further, with the use of iron-industry remains as a stratigraphic marker, are not included in the selected examples treated below.

4.2.2. TRACES OF MINERAL PALSAS ON THE HAUTES FAGNES PLATEAU (BELGIUM)*

On the Hautes Fagnes Plateau, at heights above 500 m, hundreds of enclosed depressions surrounded by a rampart are grouped in a few locations. These were interpreted, some 30 years ago, as traces of pingos.
Comparison of these depressions with present-day examples in the Arctic, drillings carried out in zones where such depressions are frequent and transverse excavations through ramparts support the following viewpoint :

1. These forms are traces of periglacial mounds and are the result of the increase in size of ice-masses in the ground.
2. These periglacial mounds appeared 10,500 years ago, in the period of the last Dryas, as established by ^{14}C dating and tephrostratigraphic features.
3. They are, in fact, traces of mineral plasas and not pingos (i.e. forms arising from the growth of segregation ice in the ground)

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* by A. Pissart.

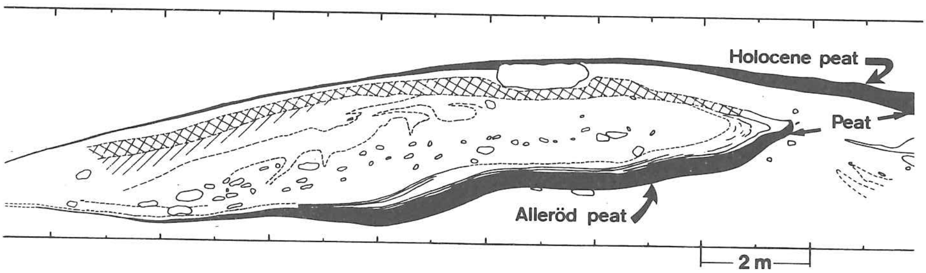

Fig. 1.
Key : Section through the rampart of the trace of a mineral palsa on the Hautes Fagnes Plateau. The Holocene surface peat extends into the closed - in bowl located on the right - hand side of the figure. The burried peat appeared between 12170 BP and 10670 BP (^{14}C dating). Scale of height unexaggerated.

as evinced by the large number of such traces, their siting on summits and the absence of sands in depth.

4. These mounds indicate that the mean annual temperature was below -4°C but above -8°C at the time of the appearrance of these features.

REFERENCE

A. PISSART & E. JUVIGNE - 1980 - Genèse et âge d'un trace de butte périglaciaire (pingo ou palse) de la Konnerzvenn (Hautes Fagnes, Belgique). Ann. Soc. Géol. Belg., t. 103, pp. 73-86.

4.2.3. THE SIGNIFICANCE OF CO2 IN THE DISSOLUTION OF LIMESTONE *

The CO_2 dissolved in water is most frequently the principal agent in its activity, whence its aggressiveness towards limestone. The importance of carbon dioxide in karst processes has led us to conduct research into the origin and mode of access of this component in waters. The major part, in temperate countries, comes generally from the metabolism of the biomass, particularly from respiration of flora. This is shown in figure 2a, in which it is apparent that,

* by C. Ek.

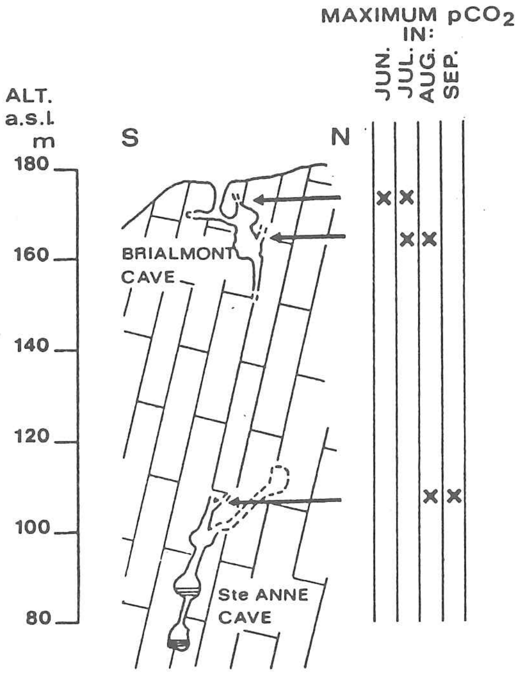

Fig. 2a. Seasonal evolution of the CO_2 content of air in fissures in Sainte-Anne and Brialmont caves. Each curve is the mean of readings taken monthly in two adjacent fissures. F1-F2 represent fissures in the upper level of Brialmont Cave. F3-F4 represent fissures in the lower level. F6-F7 represent fissures in Sainte-Anne Cave (Ek and Gewelt, 1985).
The summer maxima are very clear, the deeper the descent into the massif, the longer the delay F1-F2, then F3-F4, then F6-F7.

in the air found in fissures within caves, and for very variable levels of content, a maximum CO_2 content is systematically observed in summer.
Figure 2b explains the time-lag between maxima : the deeper the fissures under investigation lie beneath ground level, the later the maximum occurs : the CO_2 of organic origin spreads on a seasonal basis into the depths of the karst and one finds here an early measurement of it.

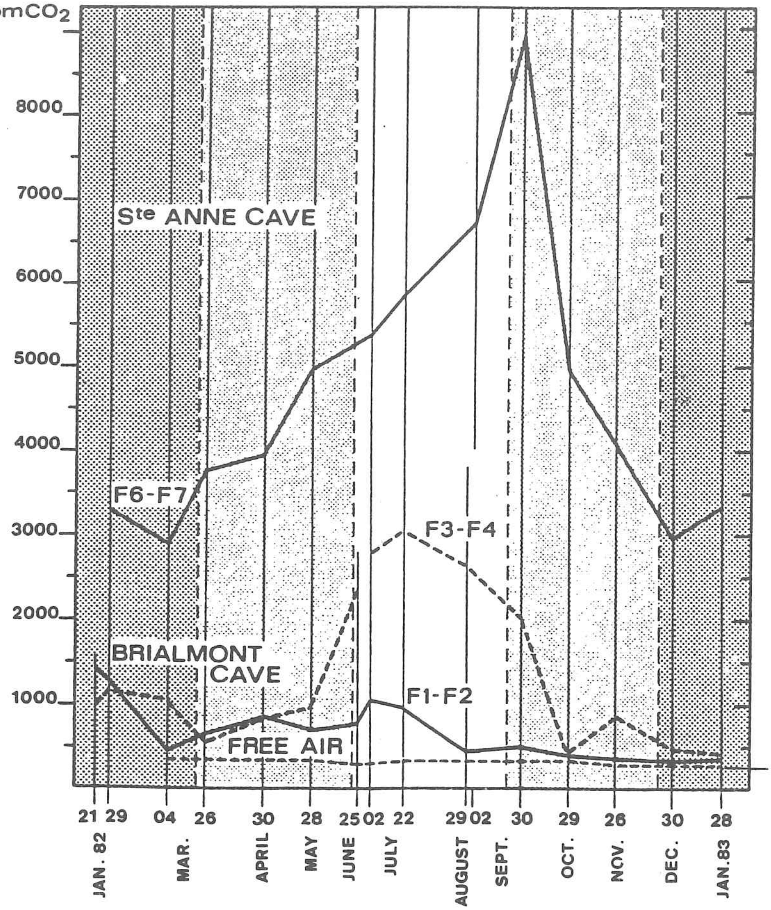

Fig. 2b. Brialmont Cave and Sainte-Anne Cave at Tilff. Schematic section. On the right, a representation of the seasonal spread of carbon dioxide as revealed by measurements shown in figure 1 (Ek and Gewelt, 1985).

REFERENCE

EK, C. & GEWELT, M., 1985. Carbon dioxide in cave atmosphere. New results in Belgium and comparison with some other countries. Earth Surface Processes and Landforms, 10 : 173-187.

4.2.3. RADIOMETRIC DATING : EXAMPLES FROM SPELEOTHEMS OF BELGIAN CAVES*

Uranium series and ^{14}C dating of calcium carbonate cave deposits are used to give a firm base of measured time to a wide range of karst studies and all others types of speleothems investigations. For instance, a new Upper Pleistocene volcanic ash fall has been discovered in speleothems dated by the $^{230}Th/^{234}U$ method (Gewelt and Juvigné, 1986). Useful comparison between palynology and ^{14}C ages of Holocene speleothems have also been carried out (Bastin and Gewelt, 1986).
Radiometric dating of speleothems may be used - beside stable isotopes studies - for reconstructing Upper Quaternary paleoclimatic

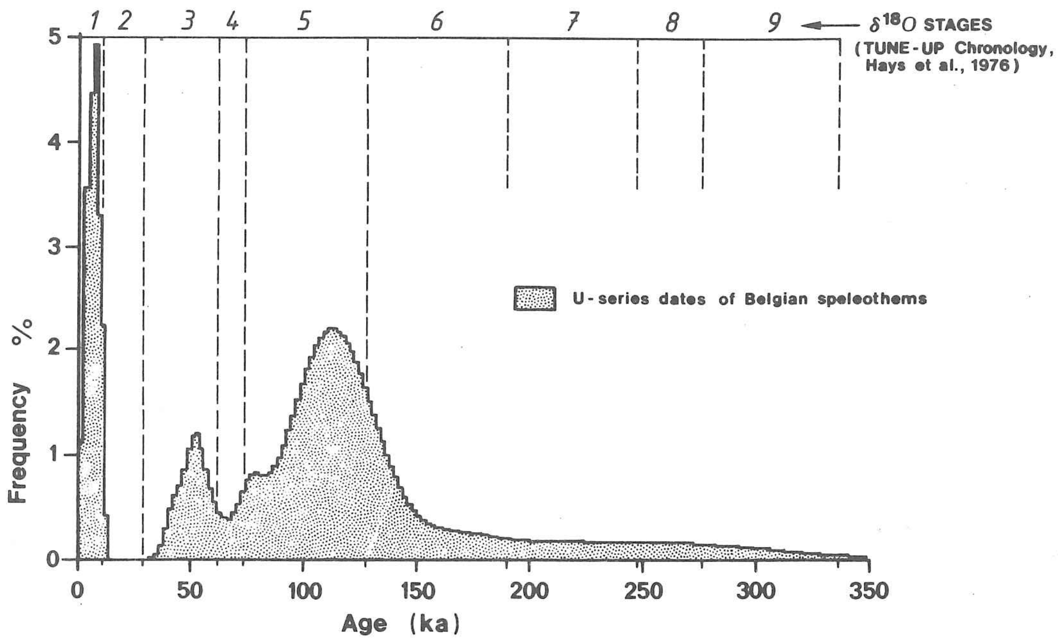

Fig. 3. Frequency curve of $^{230}Th/^{234}U$ age data of speleothems from Belgian caves, based on 51 U-series dates and 124 interpolated values (from Gewelt, 1985 and unpublished results). Frequency curve uses normal probability function and takes into account errors associated with each data. Interpoled values respect the growth rates of the speleothems and growth hiatus if any.

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* by M. Gewelt.

histories. Periods of active speleothem deposition in Belgian caves can be recognized during isotope stages 1, 3 and 5 (fig. 3). The cessation of speleothem growth during the coldest period of the last glaciation (isotope stage 2) is probably due to the presence of continuous permafrost (Gewelt, 1986), while some speleothem deposition is observed during isotope stage 4.

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GEWELT, M., 1985. Cinétique du concrétionnement dans quelques grottes belges : apport des datations ^{14}C et $^{230}Th/^{234}U$. Ann. Soc. Géol. Belg., 108 : 267-273.

GEWELT, M., 1986. Datations ^{14}C de concrétions de grottes belges : vitesses de croissance durant l'Holocène et implications paléoclimatiques, in : New Directions in Karts. Proceedings of the Anglo-French Karst Symposium, 19-26 sept. 1983, K. PATERSON & M. SWEETING, edit. Geo-Books, Norwich, 293-322.

GEWELT, M. & JUVIGNE, E., 1986. Les "Téphra de Remouchamps", un nouveau marqueur stratigraphique dans le Pléistocène supérieur daté par $^{230}Th/^{234}U$ dans des concrétions stalagmitiques. Ann. Soc. Géol. Belg., 109 : 489-497.

4.2.5. MINERALOGICAL CONTRIBUTION TO THE TEPHROSTRATIGRAPHY OF NEOPLEISTOCENE ASH-FALLS*

Volcanic ash-falls are mainly identifiable by their transparent heavy minerals in sediments of the Upper Pleistocene and the Holocene in Western Europe. However their correlation, based on mineralogical associations, poses difficult problems. In order to establish whether mineralogical separation occurred at the time of tephra transport, research has been carried out on recent ash-falls, like those from the Mount Saint Helens Volcano (U.S.A.) and from El Chichon (Mexico), enabling a model (fig. 4) to be established that determines

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* by E. Juvigné.

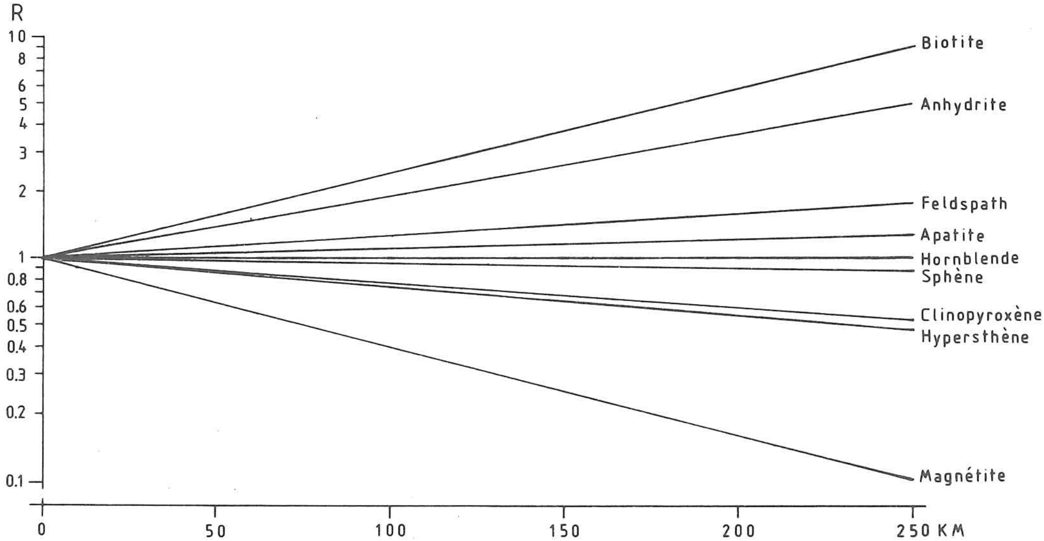

Fig. 4. Sorting of minerals in volcanic plumes using data from the Mount St. Helens ash-fall (E. Juvigné and S. Shipley, 1983) and El Chichon ash-falls (E. Juvigné, 1983). x-axis : distance from volcano.

$$\text{y-axis } R = \frac{\text{\% of the mineral/\% hornblende at distance } 0 < x < 25}{\text{\% of the mineral/\% hornblende at distance } x = 0}$$

mineralogical variations occurring in the course of tansport of volcanic plumes in(to) the stratosphere. These variations are a function of the density and the shape of the particles.

Over the last 15 years, systematic research on tephra has been carried out in three European countries.

In Belgium, this research resulted in at least 4 ash-falls being identified :

1) Laacher See tephra-Allerod period; 2) Eltville tephra dated at 16.200 B.P.; 3) Rocourt tephra dated between 60.000 and 106.000 B.P.; 4) Remouchamps tephra dated at 106.000 B.P.

In France, research carried out in the peat-bogs of the Massif Central has resulted in a considerable extension of the lobes affected by ash-fall from Pavin, Montcineyre and Chopine volcanoes. Other ash-falls of as yet unknown origine were also discovered. In each case, absolute ages were proposed based on radiometric dating and/or pollinic diagrams. Overall, these factors have led to revision of the chronostratigraphy of Late-Glacial or Holocene eruptions in the Chain of the Puys and the Monts Dore.

In Germany, the study of peaty and mineral infilling of Maar in the western Eifel has enable the volcanism of this region to be shown to be considerably older as compared with earlier chronostratigraphical data derived basically from interpretation of pollinic diagrams.

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JUVIGNE, E. 1980 - Révision de l'âge des volcans de l'Eifel occidental. Zeit. f. Geomorph., 24 : 345-355.

JUVIGNE, E. et GILOT, E. 1986 - Ages et zones de dispersion de téphra émises par les volcans du Montcyneire et du lac Pavin (Massif Central, France). Z. dt. geol. Ges., 137 : 1-11.

4.2.6. QUATERNARY SEA-LEVELS IN THE WESTERN MEDITERRANEAN*

Our research on the shoreline of Sardinia and along various Western Mediterranean coasts has enabled us to show that :

1) Beach deposits in the last interglacial (Tyrrhenian) display in Sardinia two differing facies that are non-contemporary and separated by a well defined erosive surface. The first deposit is mainly composed of fine elements (sands) and has been designated **Cala Mosca Formation.** It has it parallel in the **Rejiche Formation** in Tunisia and would correspond to the Eutyrrhenian. As for the second deposit, it is characterised by a heterometric coarse conglomerate and is termed **Santa Reparata Formation.** It is the equivalent of the Tunisian **Chebba Formation** and probably dates from the Neotyrrhenian.

2) In Sardinia, the Tyrrhenian beach is generally located at a constant altitude, between 2 and 5 metres, except locally. This testifies to the island's very great stability, during the Upper Pleistocene.

3) As an indicator of past sea-levels, the corrosion notches provide, on limestone coastlines, very precise evidence. In Southern Lazio,

* by A. Ozer.

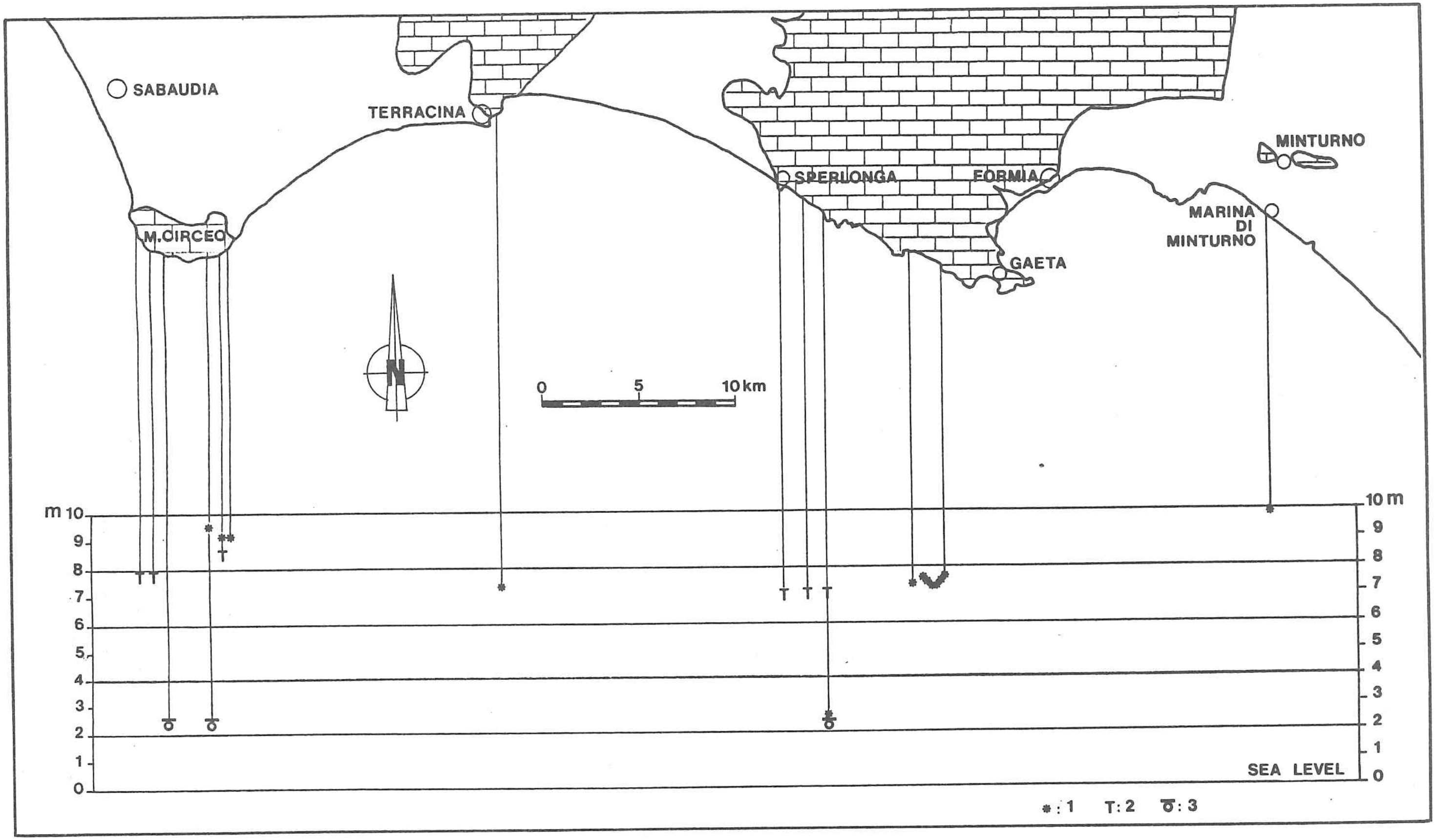

Fig. 5. Spatial and altimetric distribution of corrosion notches along the coastline of Monte Circeo-Gaeta-Minturno.
1) Altitude of the maximal concavities of the notches. 2) Altitude of the highest point of lithophage perforations. 3) Altitude of the highest point of beach deposits.

the best developed notch is contemporary with the Eutyrrhenian. The difference in altitude of these notches can only be explained by a post-tyrrhenian relative uplift of the Minturno zone (9,84 m) and the Circeo zone (9,56 m) in comparison with the Terracina-Sperlonga-Gaeta (7,40 m) (Figure 5, p. 117).

4) As much in Sardinia as in Cilento (Southern Campagna), the beaches of the Tyrrhenian are surmounted by eolianites alternating with rubified horizons. It was established, by the study of dense minerals and by the mineralogy of the clays, that the eolianites were laid down during the regressive phases of the Quaternary.

5) Finally, several oceanographical campaigns enabled us to locate 14 Quaternary shore-lines between depths of 5 and 157 metres on the Sardinian continental shelf.

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A. OZER, M. PICAZZO et A. ULZEGA - 1982. Osservazioni sulla paleogeografia delle Bocche di Bonifacio (Risultati delle campagne oceanografiche effetuate nel 1974 e nel 1979). A.I.O.L. IV, 34-1, 34-11.

A. OZER, R. PASKOFF, P. SANLAVILLE et A. ULZEGA - 1980. Essai de corrélation du Pléistocène supérieur de la Sardaigne et de la Tunisie. C.R.Ac.Sc.Paris, 291, 801-804.

4.2.7. NEOTECTONICS IN UPPER BELGIUM*

The Ardenne Massif, corresponding to Upper Belgium, constitutes the western part of the Rhenish Shield. Until the beginning of the nineteen-eighties, in speaking of the Cenozoic age, only epeirogenic movements on a limited scale, superimposed on the general uplift of the Shield, were described.

However, in 1984, a detailed morphological investigation enabled me to establish the existence, and post-oligocene activity, of radial

* by A. Demoulin

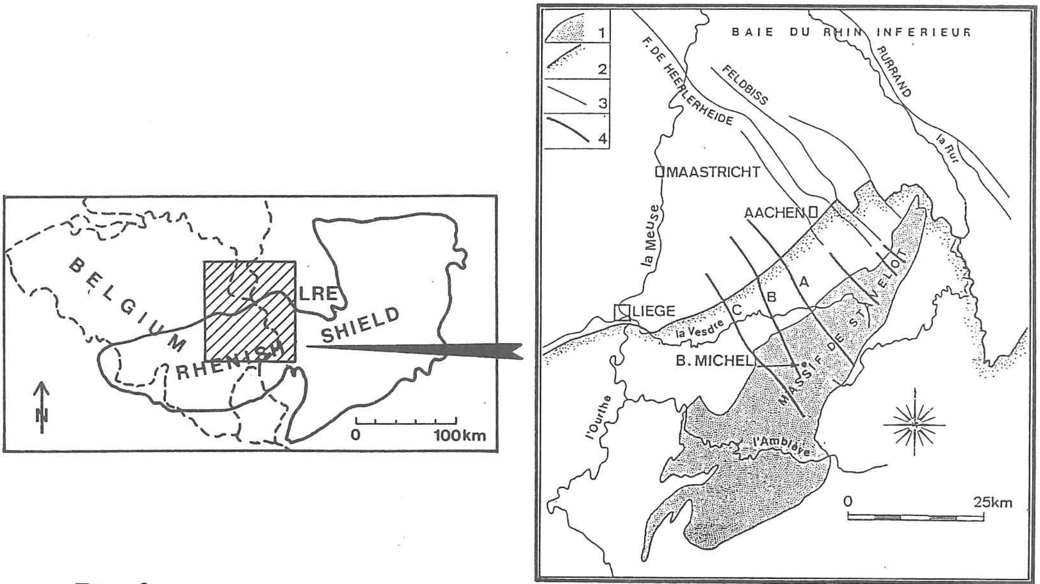

Fig. 6.
LRE : Lower Rhine Embayment.
1. Stavelot Massif
2. Limit of the Rhenish Shield
3. Faults in the Lower Rhine Embayment
4. Radial faults in northern Ardenne

faulting on a NW-SE axis in the northern Ardenne region. This part of the massif, just like the north of the Eifel, lies adjacent to the lower Rhine embayment, a subsidence zone with its western limit only some 30 km distance.
Recent activity in the faulting is indicated by the deformations it is causing in the region's tertiary planation surfaces, as well as by the evolution of the hydrographic network. Quaternary movements in the faulting is further proved by deformations in fluvial terraces.
These fractures can be related to the main fault system which developed since the Oligocene, at the time of the opening of the Lower Rhine embayment. They show thus the repercussions of the development of this rift segment on adjacent massifs. It must also be pointed out that traces of faulting appear solely in the Cambrian core in the north of the Ardenne, since, towards the South, the tectonically incompetent schistous Lower Devonian is not fractured.

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DEMOULIN A. - 1988 - Cenozoic tectonics on the Hautes Fagnes plateau (Belgium). Tectonophysics. 145, 31-41.

4.2.8. THE 8TH NOVEMBER 1983 LIEGE EARTHQUAKE*

On the 8th November 1983, a violent tremor registering 4.9 on the Richter scale and VII degrees on the M.S.K. scale shook the Liège région causing widespread damages to buildings and deep concern among the people. An inquiry among the population and computer processing of the data collected enabled the macroseismic map shown below to be drawn up.
This map is of considerable interest, both fundamental and applied. Indeed, by researching the influence of geological structure, lithology, relief and mine-workings on the configuration of the isoseisms, we were able to bring out the influence of site-effects on that configuration. Among these effects, it is mining which seems to have played a predominant part in the distribution of damages. Our present research is directed towards the study of the influence of surface formations in order to establish a microzoning of the area as a function of seismic risk.
Additionally, this map allows a hypothesis to be advanced as to the cause of the tremor. Indeed the very clear NW-SE orientation of the high intensity zones, identical to the fault-line of the Lower Rhine Graben observed by A. Demoulin (see p. 119) at a distance of less than 20 kilometers to the east of Liège, seems to indicate that the Liège tremor might well be the result of tectonic movement related to the widening of the Lower Rhine Graben.

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* by M. François.

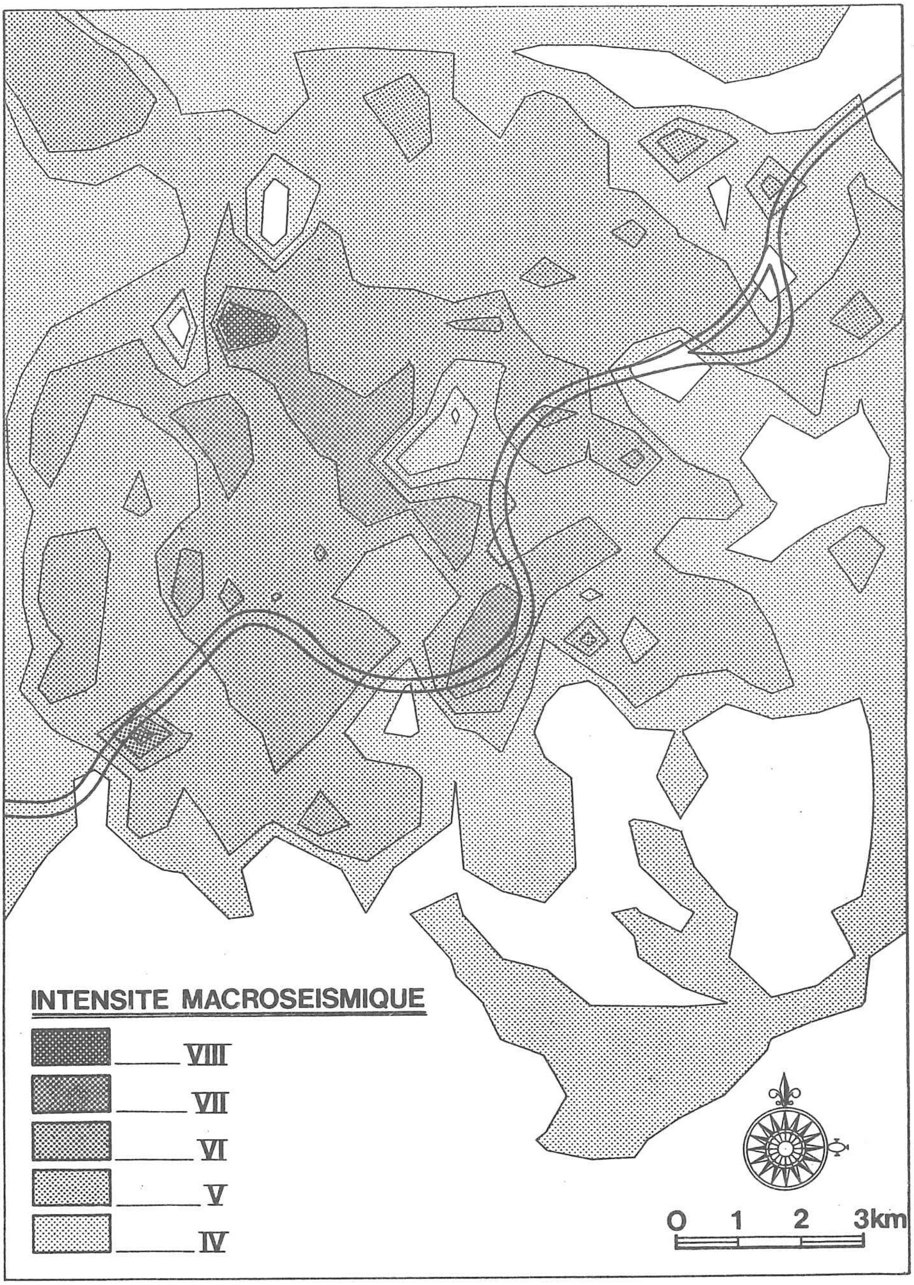

Fig. 7.
Key : Macroseismic map obtained by computer from investigation points.

4.2.9. VARIATIONS IN THE LENGTH OF ROCK SAMPLES SUBJECTED TO ALTERNATE WETTING AND DRYING*

Rock samples, mainly limestone, were subjected to repeated cycles of wetting and drying. At each cycle, these samples exhibited significant variations in length reaching 18 µm per centimetre. The degree of variation can be linked with the size of the pores and the clay content of the rocks under study. It also became clear that the samples submitted to such cycles grow progressively longer (fig. 8). Thus dilatometric study enables a process of weathering to be followed, the effectiveness of which, so often referred to, has not been clearly demonstrated.

Variations in length are only significant when the samples lose their humidity completely. The evaporation of this moisture tightly held in the rock can only occur slowly in a very dry atmosphere. Consequently this weathering process can be effective solely in climates enjoying strongly marked dry seasons.

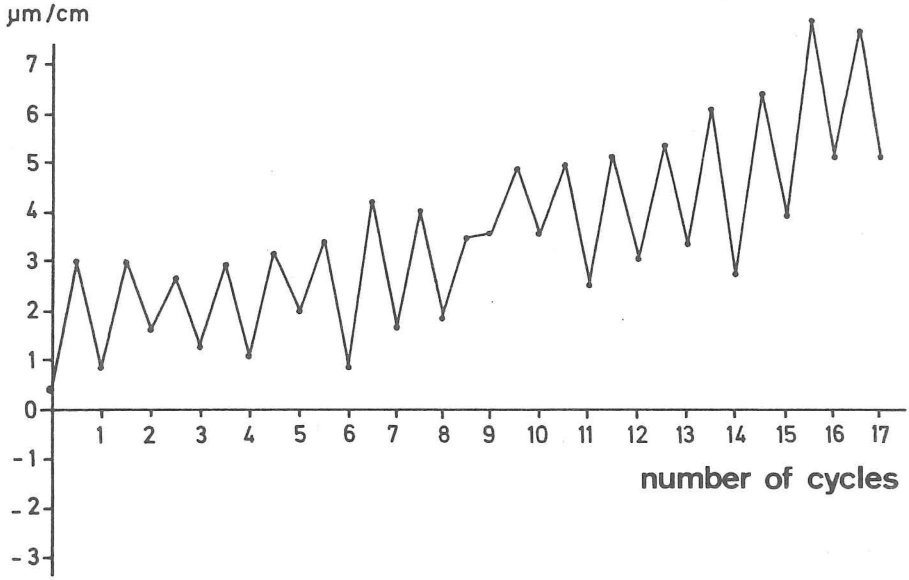

Fig. 8.

REFERENCE

HAMES, V., LAUTRIDOU, J.P., OZER, A. and PISSART, A., 1987. Dilatometric variations in rocks subjected to cycles of "wetting and drying". Géographie physique et Quaternaire, Montréal, 16, n° 3 : 345-354.

* by V. Hamès and A. Pissart.

4.2.10. SUSPENSION TRANPORTS IN THE MEUSE; EVOLUTION OVER A HUNDRED YEAR*

In 1883, some professors of Chemistry in the University of Liège took daily samples of the water from the Meuse for a one year period. They measured the quantity and analysed the nature of the load transported in solution and in suspension by the river. Similar stu ies were carried out a century later and the results were compared by drawing up a line-graph based on the rates of discharge and the quantity of materials tranported by the river. This graph is reproduced below.

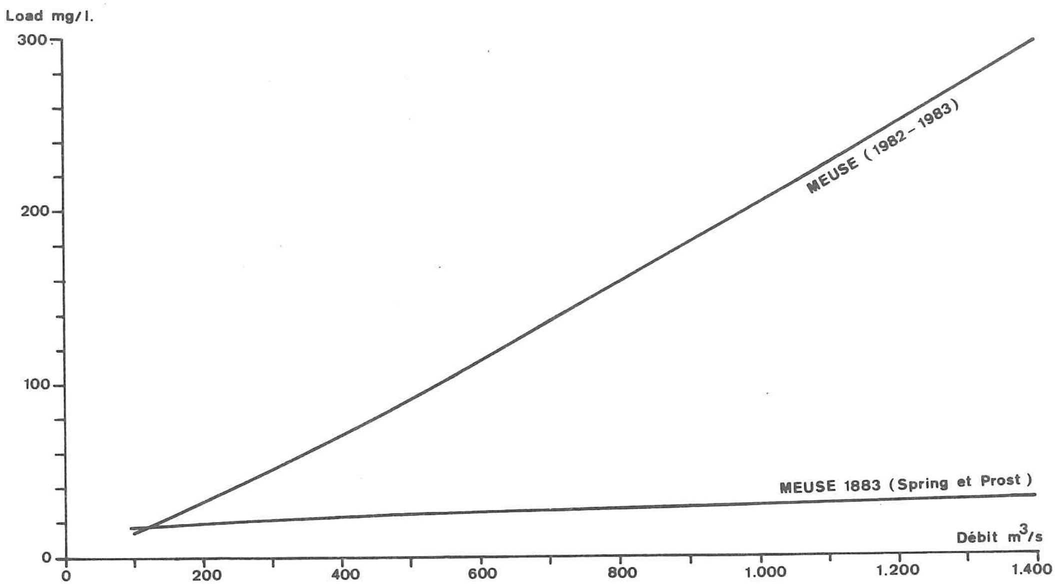

Fig. 9.

The content of elements held in solution by the Meuse has not varied over the century. On the other hand it is clear that the river now transports less sediment when discharge is low, and much more than in the past when in high flood. These charges are the result of development-work on the river bed which was artificially widened and deepened to allow navigation of ships of greater tonnage. At low discharge, the water is almost still and materials in suspension settle to the river bed. In times of spate, the now canalised river no longer floods the alluvial plain. All the sediments which

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* by A. Pissart and G. Lemin.

enter the channel are discharged (evacuated). Calculations of the rate of sedimentation on the alluvial plain during the historical period confirm this interpretation.

REFERENCE

LEMIN, G., KOCH, G., HURTGEN, C. and PISSART, A., 1987: Les transports en suspension de la Meuse, l'Ourthe et la Hoegne. Bull. Soc. Géogr. Liège. 22-23 : 39-61.

4.2.11. GEOMORPHOLOGICAL MAPPING OF A CONTACT ZONE BETWEEN THE ARDENNE AND THE CONDROZ, IN SOUTH OF BELGIUM*

Within the framework of the geomorphological cartography of Belgium (scale : 1/50.000), it was decided to draw plate 49 (Spa) which is located at the junction of differing natural regions of the country (Condruzian Ardenne, Condroz, "limestone strip", Ardenne, the geological "Fenêtre de Theux".).
The preparatory work for land surveys involves study of aerial photographs and satellite pictures which brings out very clearly the imprint which the main features of geological structure impose on surface morphology.
Geology actually plays a fundamental part in the individualisation of relief formation :

- variations in the resistance of rocks to erosion are at the origin of the formation of so-called lithological slopes.
- the fracturation pattern of the rock (with or without displacements) determines in part the hydrographic network.

The figure below provides an example of the relationship between geomorphology and geology exhibited on this map.

- the line of the valleys is quite oblique in relation to the local slope of the land and the dominant direction is that of the network of joints/separation planes in the region.

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* by F. Girolimetto.

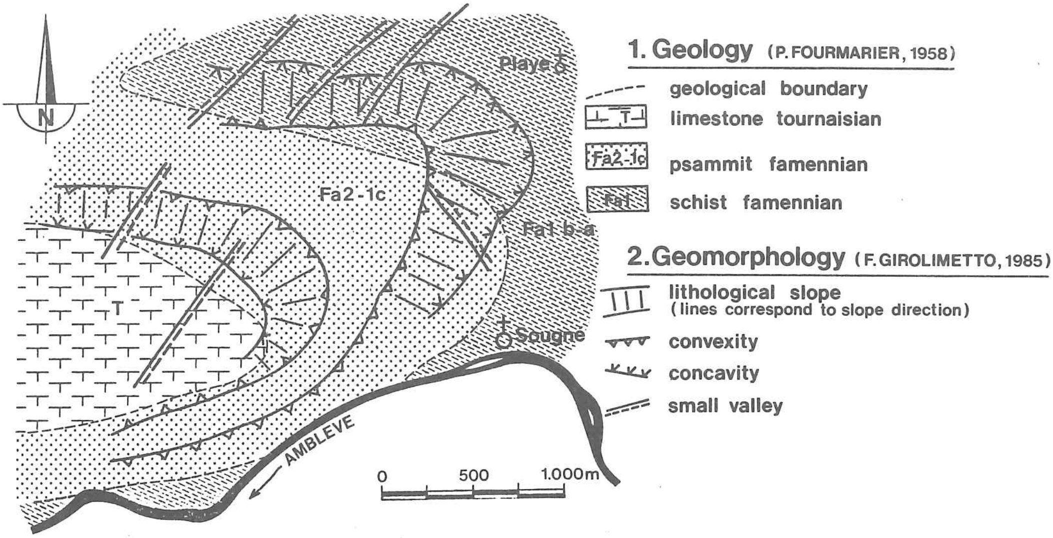

Fig. 10.

- the psammite rocks (1) of the Fa2-1c (Famennian) form summits by comparison with surrounding limestones and schists : their outcrops are limited by well defined summital convexities. Hence, the shape of these convexities corresponds to geological limits and, in the present instant, geomorphology suggests a synclinal nose that is more stubby and more turned up towards the north than is suggested by the official map. These data are confirmed by the pedological map of Belgium (which specifies the nature of the content of the soils).

Other examples occur on the plates, more particularly in the geological "Fenêtre de Theux".

The geomorphological map thus constitutes a precious tool for the geologist, especially in regions where outcrops are sparse.

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GIROLIMETTO, F., Les indices géomorphologiques de grands traits structuraux dans la Fenêtre de Theux. Ann. Soc. Géol. Belg., 109 : 621-627.

(1) psammite : micaceous sandstone.