U. S. Geological survey.
Reports. Open file series.

U. S. Geological survey.
Reports Open file series. Translations 1 to 5 (articles on engineering geology) by Mrs. Severine Britt.

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# DEPARTMENT OF THE INTERIOR

## INFORMATION SERVICE



GEOLOGICAL SURVEY

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### TRANSLATIONS OF FIVE FRENCH PAPERS RELEASED

Translations of five French papers on various phases of engineering geology have been placed in open file by the Geological Survey, Director William E. Wrather announced today.

1. "Choice of materials most suitable for ballast", by Leo Maddalena, describes the properties needed for good railroad ballast material. Important rocks of Italy and general rock types, such as granite, syenite, lavas, sandstones and limestones, are considered with respect to their structure, texture, compaction, accessory elements, porosity, alteration, and strength. Five pages.

2. "Special problem caused by the epigenetic alterations of Liassic rocks", by Henry Joly and Ninck, describes damages to the foundation of a building in Nancy due to swelling of a Jurassic shale bed. The swelling was due to the formation of calcium sulphate by chemical reaction of constituents of the shale resulting from circulation of damp air in the shale bed. Remedial measures are described. Seven pages.

3. "Protection of roads against rock falls", by Leo Maddalena, describes the relation between rock falls and the degree of fissuring and the mineralogy of the rocks involved. The characteristics of various types of rocks are outlined and suitable types of protection described. Four pages.

4. "Geology applied to modern highways", by Leo Maddalena, is a study of the contribution of geologic work to the construction of a heavy-duty highway through rugged terrain in the Apennine Mountains of Italy. Ten pages.

The above four papers are from the "Congres International des Mines, de la Metallurgie et de la Geologie Appliquee", vol. 2, Paris, 1935.

5. "Tests and researches on building stones", by M. R. L'Hermite and L. Feret, is a detailed report of tests made on nine limestones by the Laboratory of Building and Public Works, Paris, in 1943. Correlations are made between various properties of the stones such as composition, density, porosity, crushing strength, difficulty of dressing, elastic constants, permeability to water, resistance to abrasion, and thermal expansion. Thirty-one pages, twenty-one figures.

These translations, made by Mrs. Severine H. Britt, may be inspected in open files at the Geological Survey, Room 1033 (Library) Federal Works Agency Building, Washington, D. C., and in Building 12-B, Denver Federal Center, Denver Colorado. A limited number of copies of the translations have been mimeographed, and, as long as the supply lasts, copies can be obtained by those directly interested by writing the Director, U. S. Geological Survey, Washington 25, D. C.

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Translation No. 2

# SPECIAL PROBLEM CAUSED BY THE EPIGENETIC ALTERATIONS OF LIASSIC ROCKS
(A translation)

Joly, Henry and Ninck. Un cas trés particulier de désordres causés par les modifications épigénétiques de roches liasiques (Schistes à posidonies du Taorcien de Lorraine); Congres International des Mines, de la Metallurgie et de la Geologie appliquee, vol. 2, pp. 529-532, 1935.



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Translated by Mrs. Severine Britt, U. S. Geological Survey, 1947.

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A small part of the city of Nancy rests on outcrops of upper Liassic shales commonly known by local geologists as paper shales.

At the time of the construction of the "Magasins Reunis" building, the foundations deeply penetrated this shale bed. The stratum being water-bearing, a drain was set to evacuate water from the deepest foundation.

The building of the "Societe Nanceienne de Credit Industriel" on St. Jean Square in Nancy is built entirely on the same shale bed which is covered at that point by gravels from old alluvium of the Meurthe river (terrace of 15-20 meters), and by earth-fill. The deepest foundations are set on the shale bed more than 2 meters above its base. The shale is underlain by the rocky and water-bearing stratum of middle Liassic sandstone.

As anomalous conditions appeared in the basements of the building, investigations were made to find their causes and to prevent their continuation and their reoccurrence. These anomalies were very strange, especially in a part of the building recently erected. It was noticed that the concrete and the pavement of the basements had in many places raised up about 0.20 meter. Still nowhere in the building, in walls or ceilings of the different stories, could any trace of dislocation or the slightest cracking be found. Consequently, the anomalies could not

be attributed to an uneven settling of the ground under the foundations; at the very most a homogeneous settling of the ground as a unit under the foundations could have been admitted, but this would have been even more unlikely since all the foundations of the various parts of the building are not set at the same depth. Therefore, it was necessary to know first the causes of heaving of the concrete and consequently of the ground where it was set. We immediately thought of making a comparison with what happens in mines. In mining it is found that two distinct categories of ground movement may be observed: first, movement "by reaction"; second, "spontaneous" movement. To the first category belong, among others, the obstructions of galleries by convergence of the roof and the floor, the floor actually rising towards the roof, while the roof subsides by collapse or settlement. This rising of the gallery's ground is a reaction due to the driving of the gallery's piles in weak ground which acts as a plastic mass. It is noticed that this phenomenon generally occurs with rapidity.

The heaving of the ground of "Societe Nanceienne" could not be attributed to such cause, as it would have been necessary to admit the sinking of the foundations, and consequently the subsidence of the building, which is inconsistent with the absence of traces of dislocation in the building.

Spontaneous movement in mines consists of the collapse of walls of galleries or workings, or roofs of galleries or workings due to the rock beds becoming impregnated with moisture or becoming dry, and to a physical or chemical alteration of the material. Also a swelling of the rocks is often observed, due on one hand to a reduction of pressure, which is very noticeable in the walls of galleries or workings, and on the other hand, to a chemical alteration of the rock caused by the presence of damp air. This phenomenon often occurs in marls, pyritic and argillaceous shales, and in anhydrite blocks.

The anomalies noticed in the building of "Societe Nanceienne" were attributed to an action of the same category (spontaneous). These anomalies are explained by the swelling of the paper shales on which the concrete of the building's basement is set; and the swelling is produced by the decomposition in moist air of the abundant pyrite (marcasite) in those shales. Pyrite ($FeS_2$) is found in the presence of oxygen and the water of moist air, and also in the presence of lime carbonate contained in the shale. Several reactions occur, which produce iron carbonate (through the influence of $CO_2$ of damp air) and calcium sulphate. Iron carbonate is unstable and decomposes into ferric oxide and carbon dioxide; calcium sulphate dissolves in water when water is present in sufficient quantity; otherwise it crystallizes and makes a space for itself.

The crystallization of calcium sulphate occurs in the existing voids, but if there are no voids the crystals create their space by exerting pressure on the surrounding materials. The phenomenon is obvious; it occurs rapidly; it was observed in the stratum referred to in materials coming from an excavation made about 10 years ago in a building located in Nancy. There is no doubt that the phenomenon described is the cause of the anomalies seen in the building of "Societe Nanceienne".

Normally, in formations in place the decomposition occurs in a somewhat different way; the calcium sulphate is dissolved and carried away by water; iron carbonate is also carried along by water and gives the springs formed by it a characteristic precipitate of ferrous oxide.

So, in the paper shales the absence of water permits the penetration of moist air, promoting swelling, just as in mines the intensive ventilation of pyritic areas sometimes causes considerable damages and even fires.

In the case of "Societe Nanceienne", the writers made sure that the swelling of the ground was due to this phenomenon, and in the excavations made at their request, gypsum crystals (calcium sulphate) were found lining the intervals between the layers of shale, causing a considerable increase of the volume of the rock itself. The reaction is greatest along the drains set in the shale itself during and after the war. The decomposition extends, however, laterally and toward the foundations. It decreases in depth and it has been seen that 1.70 meters beneath the pavement the rock remained in its original state.

The action of water, when it washed the foundations and the surrounding ground, is now properly explained. One may understand why the swelling occurred more intensively after the "Magasins Reunis" installed the large drain emptying into the gutter of St. Thiebaut St., drying the subsoil of"Societe Nanceienne".

In short, it can be stated that all the anomalies caused in the old as well as in the new buildings of"Societe Nanceienne"are due to the molecular action accompanying the decomposition of pyrite in the "schistes cartons" leading to a swelling of the ground of a section whose maximum thickness is 1.70 meters. Up to now the foundations themselves were not reached by this action due to the compression of the ground under the foundations, preventing the penetration of air; but it is to be feared that little by little the decomposition extending laterally and to depth will reach and affect the foundations. In any case, it seems to be absolutely necessary to provide against the extension of this action as well as against the damages already incurred. The study of the means proposed as remedy is the object of the second part of the present note.

In order to determine the remedy and the means of application, it is advisable to reconsider the action which caused the anomalies so as to study it in detail:

Pyrite, lime carbonate and water exist in the "schiste carton" in place and damp air penetrates it accidentally.

Pyrite is oxidized by damp air and becomes iron sulphate; but carbonate-loaded water circulating in the shale combines with the iron to produce iron carbonate and release sulphuric acid. Sulphuric acid reacting with the lime carbonate of the rock gives hydrated lime sulphate (gypsum) by releasing carbonic acid absorbed by the damp air and water. When water is preponderant, lime sulphate is eliminated because of its solubility. Aluminum sulphates and iron alums can also be found. The skin irritations noticed by the workmen working on the wells bored in this stratum (personal observation of one of the writers) can probably be attributed to the presence of iron alums.

Consequently the succession of reactions requires dampness and oxygen. Water and air serve as vehicles of carbonic and sulphuric acids which sometimes react on limestone, sometimes on pyrite or its by-products./

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/ The phenomenon may, in reality, be more complex; we have found in the layers of shale other reactive minerals; but we refer to what is said on the decomposition of pyrite in the remarkable work of M. A. Lacroix: Mineralogie de la France et de ses colonies, t. II, p. 575 (Mineralogy of France and its colonies).

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These chemical considerations pointing out the development of the phenomenon also indicate that to prevent it, it would suffice to stop the circulation of damp air which could only be effected by filling all the voids with an air-tight substance. This is the final remedy that was considered. It remained to choose the impervious substance and to determine the method of using it.

We first thought of using shale oil or heavy oil, which would have filled up all the voids, and consequently excluded oxygen, but the contractors justly pointed out that, on one hand oil could cause damages in the concrete of the foundations

and, on the other hand, being very fluid, the oil could have been eliminated by sweating or by sudden raising of the water level. Consequently, we adopted the solution of using chemical products and cement to be injected under pressure into the shale in every point of the subsoil of the building. Naturally, we also provided for the obstruction of all drains existing in the subsoil.

The conclusions of our study were adopted by the company, proprietor of the building.

The work was successfully carried out, consisting of drilling a great number of borings, 1.50 to 2.50 meters deep in which combined chemical products and cement were systematically and alternately injected up to the pressure of 1 kilogram, and the concrete and pavement of the basement of the building were repaired, so that everything was completed toward the middle of 1932. Since then, no trace whatsoever of movement or disorder was disclosed, in spite of several checkings made at long intervals, and it seems that the remedy used was sound.

## CONCLUSIONS

It seemed interesting to correlate these particular facts, because of the determination of the causes of the disorders which we were able to establish with assurance, and also because of the effectiveness of the remedy which helped to bring to light the effects of the ground treatment by injection of combined cement and chemical products.

Consequently we have determined that the disorders caused in the basement of "Societe Nanceienne de Credit Industriel", St. Jean Square, are due to a swelling of the ground under chemical reaction caused by circulation of damp air in the paper shales bed, and that these important damages were activated by drains made under the pavement to dispose of water from the shale. Later on, drainage works in the

vicinity considerably changed the conditions and caused the rapid development of the swelling.

Fortunately, all the damages could be repaired and above all the cause of the trouble was combatted and finally overcome by the use of the method of cement injection, and of ground treatment by appropriate chemical products.