RUDOLF ONDRÁŠIK*

THE INFLUENCE OF WEATHERING ON THE ENGINEERING PROPERTIES OF ANDESITES

(Fig. 1—19)

Резюме: В статьи разбираются результаты выветривания неогеновых андезитов на территории Словакии. Автор анализирует процессы выветривания, оценивает влияние выветрваня на зменение физико-механических свойств андезитов и предлагает количественную оценку степени их выветрелости. Одновременно проводит анализ развития кор выветривания андезитов на территории Словакии.

Abstract. The paper deals with the weathering of Neogene andesites in the Slovak territory. The author analyzes the primary processes participating in the weathering, evaluate their influence on the change of engineering properties of andesites and presents a semiquantitative evaluation of their weathering grade. He analyzes also the evolution of andesite crust of weathering in the Slovak territory.

Introduction

Andesites in Slovakia belong to the most widespread rocks which suit well as foundation rock and as construction material. However, their engineering properties are frequently worsened by intense weathering. To reduce engineering geological investigations expenses and to avoid an incorrect use of unsuitable altered andesites in more pretentious constructions it is necessary to find out the influence of weathering on their engineering properties and to find appropriate quantitative indicators of the weathering grade. Furthemore it is important to know the time dependence and depth of weathering as well as its regional nature and extention.

Concepts and Definitions

Weathering is the sum of physical, physio-chemical and biochemical processes which are altering the composition, state and properties of rocks in the upper part of the earth's crust under the influence of the atmospheric, hydrospheric and biospheric agents and also activity by man (V. A. Priklonskij 1955).

The upper part of the earth's crust in which the rocks are submitted to the atmosphere, hydrosphere and biosphere affect is called *the zone of weathering*. According to local conditions, mainly the topography and the depth of the groundwater table and its regime, this zone may reach from some tens to several hundreds meters.

The physical and chemical (physio-chemical and biochemical) processes take place simultaneously in the zone of weathering. Under certain conditions the physical.

* RNDr. R. Ondrášik, CSc., Dept. of Engineering geology and hydrogeology, Faculty of Natural Sciences of the Comenius University, Gottwaldovo nám. 2, 886 02 Bratislava

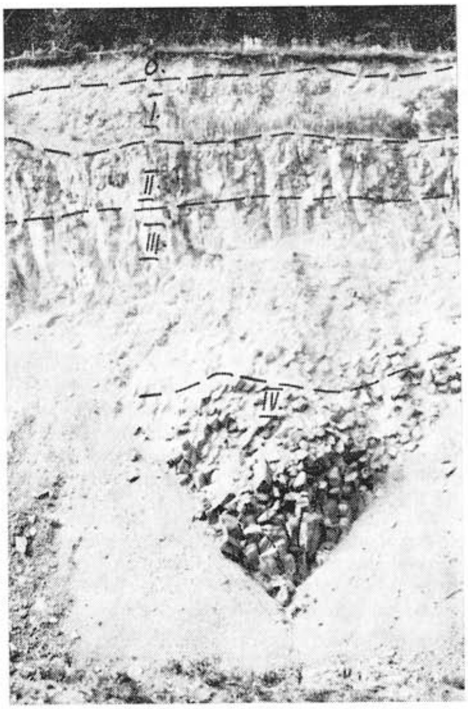


Fig. 1. The Fitzberg Quarry wall near Krupina (Central Slovakia) in pyroxenic andesites. Intensely weathered andesite in the upper part of the quarry represents the remnants of the Neogene crust of weathering. Individual horizons of the crust of weathering I—IV are indicated in the photograph.

processes may predominate causing the rock *disintegration*, while under another conditions the chemical processes may predominate causing the rock *decomposition*. Thus a deep gradual alternation of all the rock properties takes place, and quite new engineering geological types of rock originate within the zone of weathering forming *the crust of weathering*.

The development of the weathering crust depends both on the rock properties (internal conditions) and on the environmental conditions, such as climatic, geostructural, hydrogeological, geomorphological and biological (external conditions). The nearer to the surface the greater is the influence of the external conditions, from which namely the climate influences decisively the weathering of rock.

The intensity of alterations in composition, physical state and properties of rock within the crust of weathering changes with the depth. Rock alterations are less manifest in the depth of the rock mass. Considerable changes may take place in the subsurface, so that the rock acquires quite new properties. The parts of vertical profile of the weathering crust in which the lithological-petrographical properties of rocks are similar, but substantially different from the neighbouring higher or lower parts of the profile are called *the horizons of the weathering crust* (Fig. 1, 2).

Changes in Engineering Properties Due to Weathering of Andesites

In more advanced stages of weathering the andesites acquire a conspicuous character of soil. However, in this study attention is directed mainly to the initial phases of weathering. The initial changes in the composition of andesites during weathering are frequently incipient and in a perfunctory evaluation they may pass unobserved. Even so such initial changes substantially alter the engineering properties of andesites.

In the initial veathering phases of andesites, the most decisive role is played by the presence of connected microfractures which permit water and air to penetrate into the rock material. The tests of air permeability and saturation moisture capacity point to the presence of connected microfractures even in fresh andesites (Fig. 3). Even in the soundest andesites the saturation moisture content (in weight) is greater than 0.2 % which means that the connected microfractures represent about 0.5 % of the total rock volume (Fig. 4).

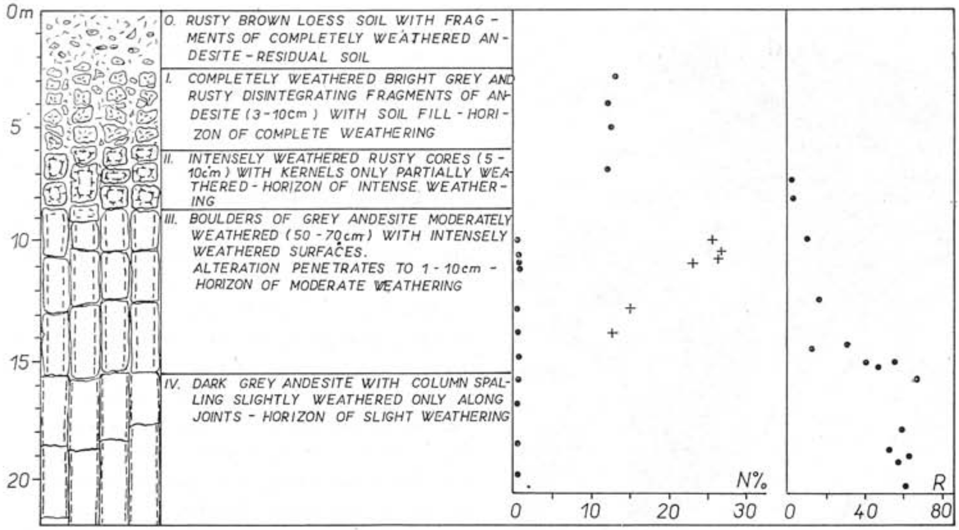


Fig. 2. Characteristics of individual horizons of the crust of weathering of pyroxenic andesite in the Fitzberg Quarry near Krupina (in Fig. 1) and the indicator of their weathering grade (saturation moisture content N by weight). Crosses indicate the values for the weathered exterior of the fragments. The „in situ“ rock characteristics in the rock mass are indicated by the rebound height (R) of Schmidt's rebound hammer, type M.

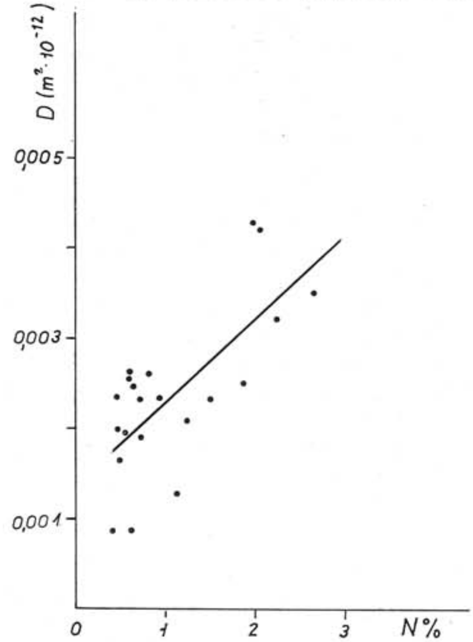


Fig. 3. Relationship between the air permeability (D) and the saturation moisture content (N) of the pyroxenic andesite from the quarry near the village of Teplička (Central Slovakia).

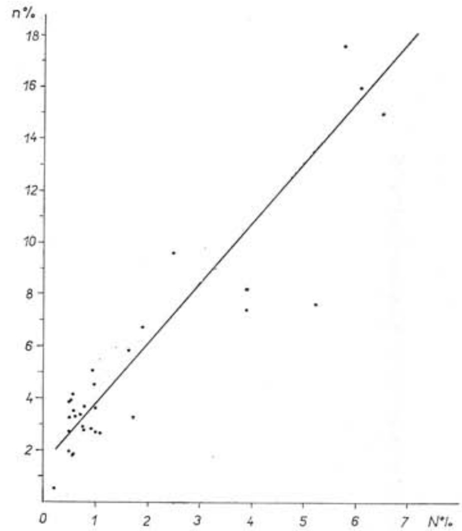


Fig. 4. Dependence of saturation moisture content (N) on the porosity (n) of the pyroxenic andesite taken from the quarry near Teplička.

Fig. 5. Zonal weathering of boulders of pyroxenic andesite in the horizon of slight weathering (III) in the Fitzberg Quarry wall (in Fig. 1).

The basic types of andesites are more resistant to weathering in the initial stages than are more acidic andesites. Owing to the denser texture basic andesites contain less microfractures than the acid types of andesites. Yet individual minerals weather in the opposite direction, from more basic to more acid ones. At a certain stage of rock disintegration, when air and water access is facilitated, a lesser resistance of basic minerals becomes manifest and a quicker weathering sets on in more basic types of andesites. Andesites are also less resistant in the vicinity of tectonically affected zones due to incrofracturing.

The primary proces of andesite weathering is the hydration and hydrolysis which occur in connection with the penetration of dissociated water solutions into the rock. The increased volume of the hydratel rock parts will result in the widening of existing and development of new microfractures. This causes an increase in permeability, access of further water into the rock and an increase in intensity of weathering (Fig. 5). Hydrolysis of silicate minerals losens appropriate lattice cations (mainly Ca^{+}, Mg^{+2}, Na^{+}, K^{+}) and facilitates their transition to solution. Meanwhile the texture of the surficial silicate lattice layer changes and its gradual decomposition takes place with simultaneous formation of secondary minerals. Among the secondary minerals of the epidote, chlorite, clay minerals (illite and kaolinite) and hydro-

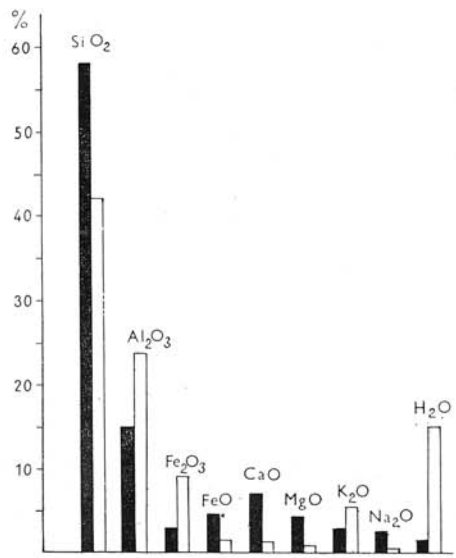
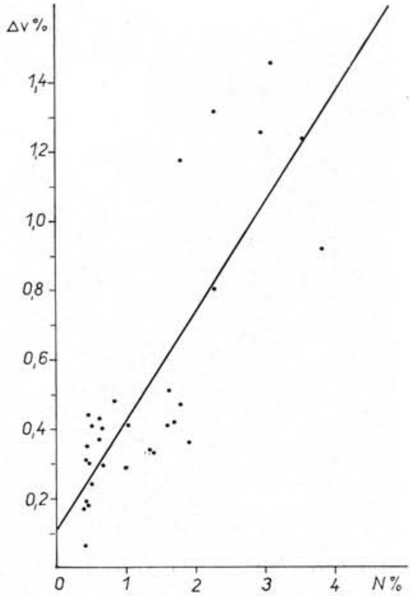


Fig. 6. The content of main chemical constituents of the pyroxenic andesitefrom the Fitzberg Quarry near Krupina taken from a sound core (black columns) of fragment (in Fig. 2) and from its weathered exterior (white columns). The chemical analysis was carried out in the laboratory of the Geological Institute, Faculty of Natural Sciences of the Comenius University.

Fig. 7. Relationship between the increased volume ($\triangle$ V) and the saturation moisture content (N) established during saturation test on the pyroxenic andesite taken from the quarry near Tepličky.



xides. Although some silica as SiO_2 is removed during weathering. Al^{+3} which is also released during this decomposition is incorporated in the lattice structure of secondary minerals. Some K^+ is also fixed to the secondary minerals. Fe^{+2} passes into immobile hydroxides (Fig. 6). Under certain circumstances if the concentration of carbonates exceeds, under given partial pressure-temperature conditions, the limit of solubility, some Ca^{+2} is fixed in the form of calcite. The intensity of hydrolysis increases with the temperature and moisture.

Comprehensibly, such deep textural changes of the rock, and first of all the volume unsteadiness of a considerable part of the secondary minerals in touch with water, causes reduction in the resistance of andesites to further weathering, especially in conditions of extreme temperature and moisture changes.

Under changing conditions of temperature and humidity, considerable physical changes take place also in fresh andesites. Volume changes due to temperature changes near the earth's surface in individual primary minerals attain hundredths, maximally even above tenths of percent (P. Clark 1966). Even if these volume changes are slight they result in sustained stress changes in the rock, enlargement of the existing microfractures, and eventually in the creation of new microfractures. However, volume changes in minerals due to temperature changes would not suffice to cause by themselves the disintegration of the rock (E. C. Roth 1965). Very important role plays at this process water and water vapour which are practically always present in the rock in humid areas, however, are drawn immediately in the enlarged or newly opened microfractures by capillary suction. Thus adsorption and pore pressure are increased. Due to capillary and adsorption pressure, enlargement of rock volume takes place (Fig. 7). In laboratory tests a volume increase by 0.06 % of the fresh andesite sample took place during saturation moisture content even under the load of 10.5 MPa. The thickness of the small water layers fixed by sorption may attain up to several tenths of micron according to B. V. Derjagin and E. D. Obuchov (in J. S. Romm 1966) and the pressure up to some thousands MPa according to S. V. Derjagin (in A. G. Černjachovskij 1968). Upon repeated closing of the microfractures in reverse temperature change, the water is not completely pressed out of them and is manifest by wedging effects. The more intense the temperature and humidity changes and the more frequently they occur the more intense is the enlargement and creation of microfractures.

The microfractures are often space oriented in the andesites. The occurrence of preferential microfracture orientation in andesites is conditioned mainly by the oriented

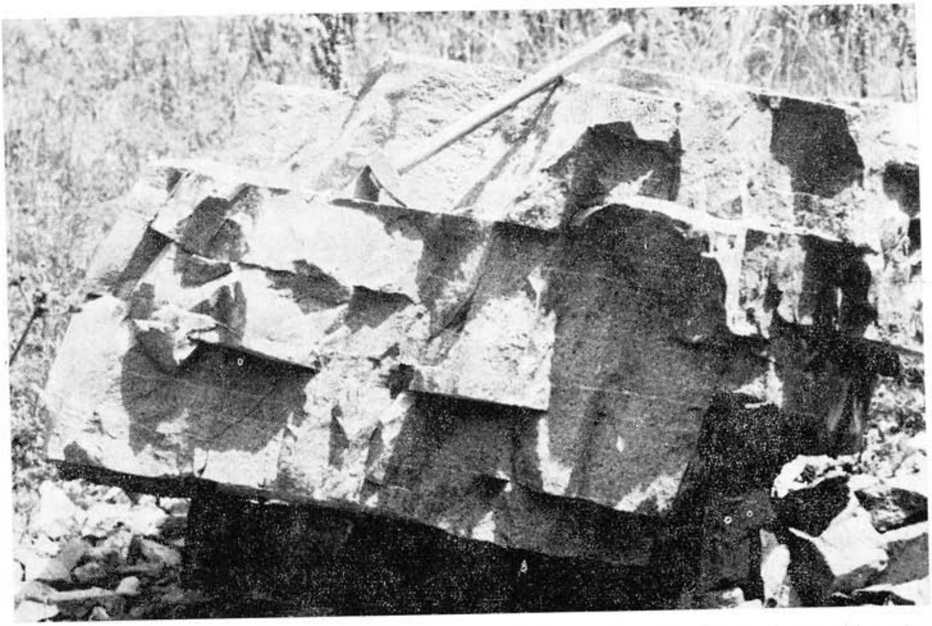


Fig. 8. Disintegration of pyroxenic andesite starting along fractures occurring on the planes of lamination. The Quarry near Dolný Tisovník (Central Slovakia).

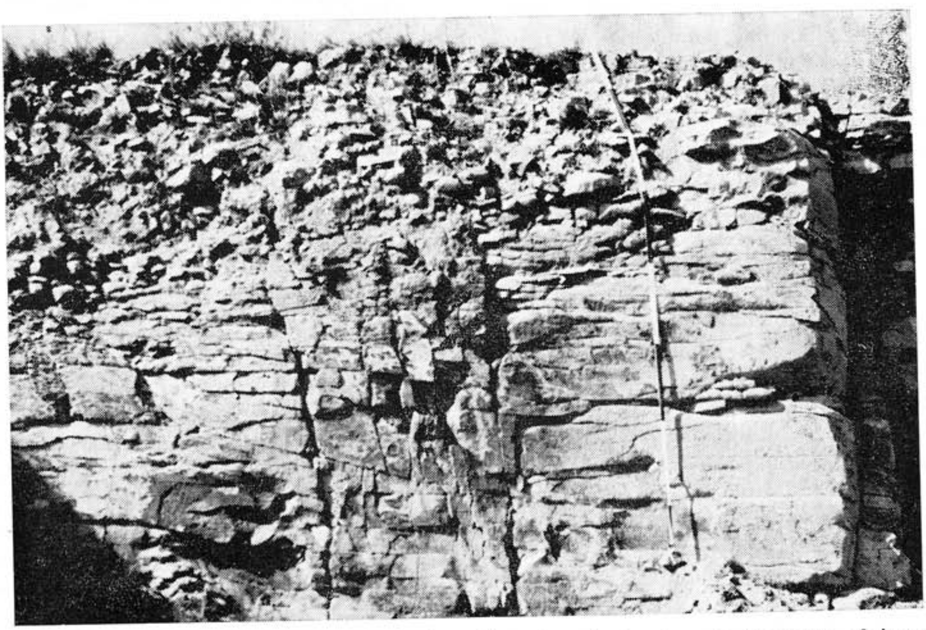


Fig. 9. Disintegration of pyroxenic andesite with oriented structure in the zone of intense temperature and moisture oscillation. The upper part of the quarry wall near Dolný Tisovník (Central Slovakia).

Fig. 10. Unsorted boulders of propylitized andesite in the rip-rapofthe earth dam of the East Slovakian water reservoir. The intense disintegration of andesite by its weathering is seen on the right side of the photography. Big bloks in the lower part were brought in only during the reconstruction of the rip-rap.

structures (e. g. parallel). Microfractures then occur and widen along the cleavage planes of tabular and layer-lattice minerals. Within connection of enlarged microfarctures a network of weathering fractures is formed near the surface of the rock mass. This network follows the primary joint and tectonic fracture systems particularly those that are parallel to the terrain surface. In andesites with parallel structure, a platy disintegration is frequently observed in the zone of weathering (Fig. 8, 9).

Finally the wedging effects of capillary water and of that fixed by adsorption in the microfractures in cooperation with other physical and physio-chemical processes result in the total disintegration of the rock. However, in the zone of weathering under natural conditions this process is very slow. Fresh andesite is resistant to weathering. Andesite already partly or slightly weathered is usually protected by surficial material eventually eluvial horizons against extreme changes of humidity and temperature. If, however, in an artificial cut slightly weathered andesite is exposed by removal of the protective cover, the process of disintegration may attain considerable intensity and adversely influence the durability of the construction work. Thus, for instance, propylitized and slightly weathered andesite used in the rip-rap of the peripheral dam of the Podvihorlat water reservoir in the Eastern Slovakia began to disintegrate during the initial years of its operation. After 8 years, expensive reconstruction of the rip-rap had to be undertaken (Fig. 10, 11).

Internal pressures which result from capillary and adsorption water in the microfractures are obviously cause for decreased strength of moist andesite as compared to dry andesite. A partial drying out of water the microfractures takes place in the

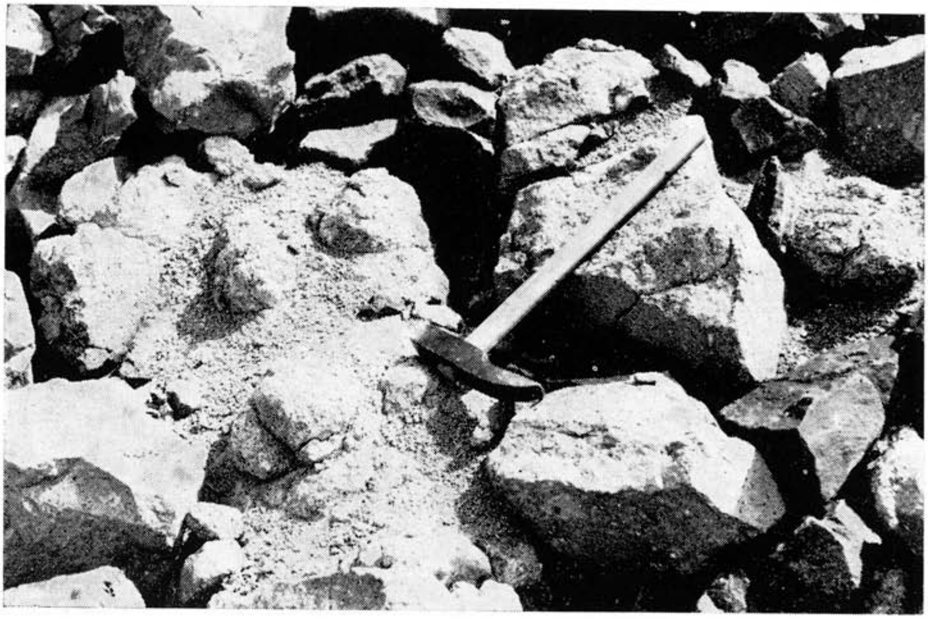


Fig. 11. Disintegration character of the propylitized pyroxenic andesite under conditions of extreme moisture and temperature changes in the rip-rap of the East Slovakian water reservoir dam in Fig. 10.

fragments of andesite after breaking off from the rock mass. A release of the internal stress simultaneously takes place by rock loosening. It is accompanied by enlargement of the microfractures. As a result, engineering properties of andesite are changed (Fig. 12, 15, 16). Also drying of water from the microfractures, and release of the internal stress cause the gradual loss of cleavage of andesites in fragments.

Ice-wedging by freezing is the most marked process of mechanical weathering in our climatic conditions. However, it is necessary to bear in mind that a whole series

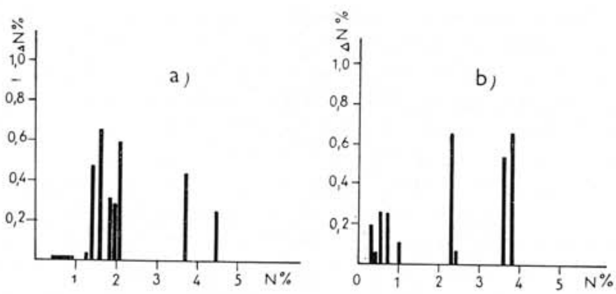


Fig. 12. Saturation moisture content increase (N) of pyroxenic andesite sample taken from the quarry near Tepličky after freezing tests under 25 cycles of freezing to temperature —20 °C and repeated thawing. Saturation moisture content increase occurred in all samples taken from the rock mass (b), as to samples from the old dump (a) it occurred only in the weathered ones in which the saturation moisture content (N) is greater than 1 %.

of physio-chemical processes takes place in the frozen rock. The affects of volume changes caused by freezing water is of primary importance. In a temperature decrease below freezing water in the macrofractures freezes followed by the freezing of water in the microfractures. The influence of capillary forces on the water freezing point is documented by the graph constructed according to data of T. Borovik — Romanov (in J. M. Sergejev 1959; Fig. 13).

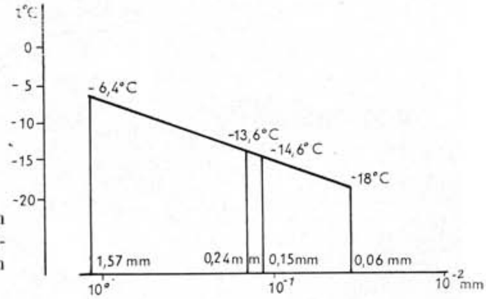


Fig. 13. Dependence of water freezing in capillaries related to their diameter (According to T. Borovik — Romanová, in J. M. Sergejev 1959).

Adsorbed water freezes gradually from exteranal to internal layered water. Meanwhile according to Bonyoncos — Mc Cool observation (in A. M. Bloch 1969) part of strongly bound water did not freeze even at a temperature of —78 °C. The freezing sequence of individual adsorbed layers of water is confirmed also by Kato's observations. In a series of minerals, he observed several summits of exothermic reactions connected with the release of heat in freezing (in A. M. Bloch 1969). Apart from this the water freezing point is influenced also by the composition and concentration of substances dissolved in water and in clay minerals, for instance, also the absorbed ions.

The initial freezing of water in the macrofractures reduces the access of additional water into the rock. However, as the temperature persists below the freezing point, a gradual diffusion of water from microfractures towards the ice crystallization centres takes place in the rock. With increased saturation of the rock, effects of freezing are intensified. This is why more intense manifestations of destructive freezing effects take place where the rock material freezes only from one side exposed to low temperatures while the other side is saturated by water. This was confirmed also by the observations of A. E. Corte (1969). Such conditions exist, for instance, above the foundations of piers (Fig. 14), in revetment and rip-rap material of fills and dikes of water reservoirs. This will require a model adjustment also by the testing techniques.

Indicators of Andesite Weathering Degree

It results from the above said that frost-resistance of rocks is not a simple function of porosity and permeability, but it is determined also by structural and petrographic characteristics of rocks and by the conditions of their water saturation. The frost-resistance is decreased mainly by the amount of connected pores and macrofractures of sufficient size to permit water to freeze at a temperature slightly below 0 °C. Under natural conditions rocks are not as a rule fully saturated with water. During water

Fig. 14. Rupter of the ashlar stones and concrete by the action of capillary suction of water and its freezing in the surficial part of the ashlar stones and concrete in the lower portion of the pier wall.

freezing in andesite, a diffusion of water from the warmer interior of the rock to its surface takes place where more extreme temperature oscillations exist. In connection with the migration of moisture and oxidation as well as hydratation and hydrolysis of minerals in the surficial part of rock fragments to a depth of several centimeters takes place.

The mechanical disintegration of rocks is influenced also by crystallization of salts from solutions penetrating the rock. Even if the pressure of crystallizing salts on the pore and fracture walls is not great (from 7 Pa to 40 Pa according to V. D. Kuznecov 1953), it may lead to their intense disintegration. The rapid weatherability test of rocks in Na_2SO_4 solution, or the sodium sulphate soundness test is based on this principle. Under natural conditions, however, this process does not continue to accelerate the rate of mechanical disintegration. From a modelling view point of natural conditions more justified is the disintegration test in which the origin and enlargement of microfractures by hydration effects occur as the result of stress changes in the rock during extreme temperature and moisture changes.

A considerable increase of microfractures takes place during the inital phases of weathering of andesites. This is manifest not only in the changes of dry density, permeability, saturation moisture content and ultrasonic pulse velocity, but also in the strength and susceptibility to further weathering.

The relationship between the engineering properties and the weathering rate of andesite is further complicated by mineralogical changes during weathering. There is a decisive loss of strength and an increase of deformation of andesite in the early stages of weathering, particularly with the reduction of crystal energy as chemical bonds are changed in the weathering process. However, as weathering progresses and secondary minerals are formed, some strength properties of the altered rock are increased. The rate of decrease of the modulus of deformation as a result of weathering is also lessened. This is documented also by the correlation of physical properties detected in the laboratory on cube samples (Fig. 15, 16). The ultrasonic

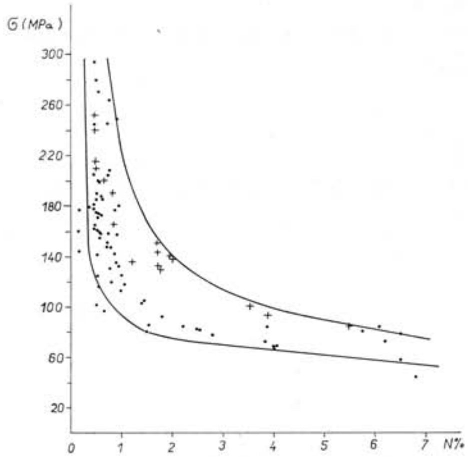


Fig. 15. Relationship between the uniaxial compression strength (σ) and the saturation moisture content (N) of the pyroxenic andesite taken from the quarry near Tepličky. Points indicate the values of the test results made on samples taken from the rock wall, crosses indicate the values obtained from samples taken from the old dump.

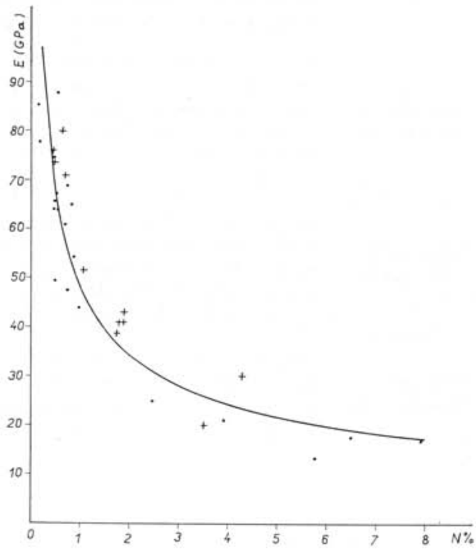


Fig. 16. Relationship between the modulus of elasticity (E) and the saturation moisture content (N) of the pyroxenic andesite taken from the quarry near Tepličky. Points indicate the values from the test results made on samples from the rock wall, crosses indicate those from the old dump.

pulse velocity has a similar course (Fig. 17). That an increase of saturation moisture content in weathered andesites, apart from microfractures, participates also the sorption capacity of newly formed clay minerals is proved by the fact that in some cases of more weathered andesites, the moisture adsorption is greater than the corresponding pore volume in dry state (J. Nešvara — R. Ondrášik 1975).

With regard to the above mentioned circumstances, dry density, moisture saturation content and ultrasonic pulse velocity can be well applied as an indicator of the andesite weathering grade (Tab. 1). From these the saturation moisture content is detectable most simply and reliably and for this it was chosen as function of the weathering grade indicator.

Table 1

Weathering Grade	Macroscopic Characteristic	Saturation moisture content N (% by weight)	Dry density d(gcm^{-3})	Ultrasonic pulse velocity v (ms^{-1})
Unweathered	Dark grey colour in general, light grey feldspars with glassy lustre, black shiny pyroxenes. Andesite is broken with difficulty by hammer	< 1	> 2.6	> 4250
Slightly Weathered	Grey in general with rusty coating along joints. Dirty white feldspars with dull lustre, black pyroxenes with dull lustre. Individual fragments broken with difficulty by hammer	1—2.5	2.5—2.6	3750—4250
Moderately Weathered	Rusty grey colour in general, dirty white feldspars with dull to earthy lustre, brownish black pyroxenes with earthy lustre. Frafments are easily broken by hammer	2.6—6	2.3—2.5	3000—3750
Intensely Weathered	Bright grey colour in general or rusty, dirty white or rusty, earthy feldspars, rusty, earthy pyroxenes. Fragments breakable in hand	> 6	< 2.3	< 3000

Regional Development of the Crust of Weathering in the West Carpathian Andesites

The weathering of andesite bodies forming on the etrth's surface began immediately after their formation. It was influenced by the then existing humid awrm climate and the high content of CO_2 and also of H_2S present in the air. In addition to the atmospheric agents, the penetrating hydrothermal solutions participated in the alteration of andesite mainly along the fault zones. This further accelerated the rate of weathering. The weathering was accompanied by the surface erosion of the andesite bodies before they were burried by younger lava flows or pyroclastic material. As a result, few andesite bodies were preserved in their original form. Rathered weathered surfaces of andesite bodies give proof to a temporary calming or cessation of volcanic activity between its main phases.

The present relief of the Central Slovakian volcanites in its rough features formed at the end of the Neogene (Pannonian) after the calming of the main phases of the volcanic activity (E. Mazúr 1962). Under subtrapical climatic conditions during a long-lasting period of tectonic stability, intense weathering and levelling of the surface of neovolcanites took place. Remnants of relatively thick neogene crusts of weathering are found on levelled surfaces from this period (Fig. 18). Characteristic for them is the spheroidal weathering as a result of intense zonal weathering of individual andesite blocks along joints. The external zones of individual rock blocks along the joints represented the zone of intense substance exchange between the rock

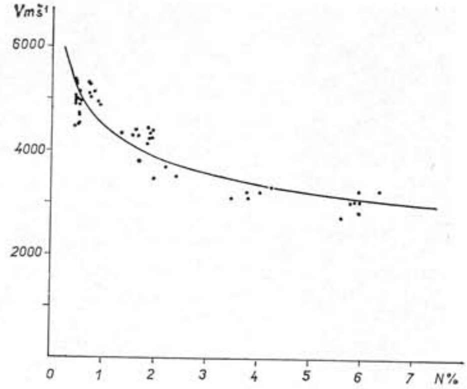


Fig. 17. Relationship between the ultrasonic pulse velocity (V) and the saturation moisture content (N) in the test samples of pyroxenic andesite taken from the quarry near Tepličky.

and the environment. As a result, there is intense surface decomposition. However, the interior of the rock blocks is almost untouched by weathering. The more rock surface that is exposed, as for example where jointing is well developed, deeper penetration of the weathering agent results in more severe weathering and spalling of the rock surface. The intensity of this process decreases with the depth. Naturally, apart from the depth below the surface, the opening of joints, their filling and to some certain extent even the orientation of the joints influence the decomposition of the andesite. The spheroidal disintegration of rocks thus weathered is manifested only alter their exposure to surface weathering agents. Rapid disintegration of the outer mantle occurs through the influence of the temperature and moisture fluctuations (Fig. 19).

In the quaternary as a whole, physical weathering predominates mainly in alternating freezing and thawing. For this reason the products of mechanical andesite disintegration in the recent eluvium predominate over the products of chemical decomposition. The thickness of the eluvium is determined by the depth of moisture

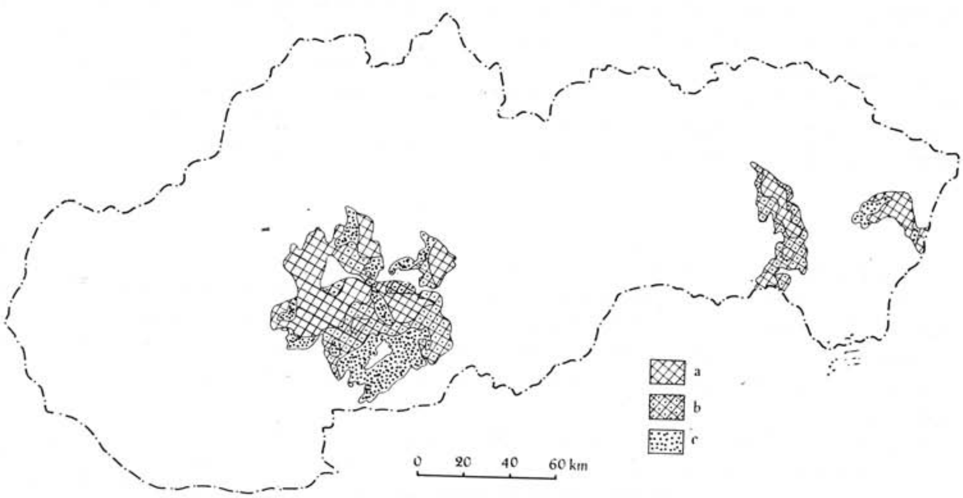


Fig. 18. Extention of andesite and tuffs weathering crust in the Slovak territory. a. Quaternary crust of weathering predominates. b. Quaternary crust of weathering and remnants of Neogene weathering crust alternately predominate. c. Remnants of Neogene weathering crust predominate.

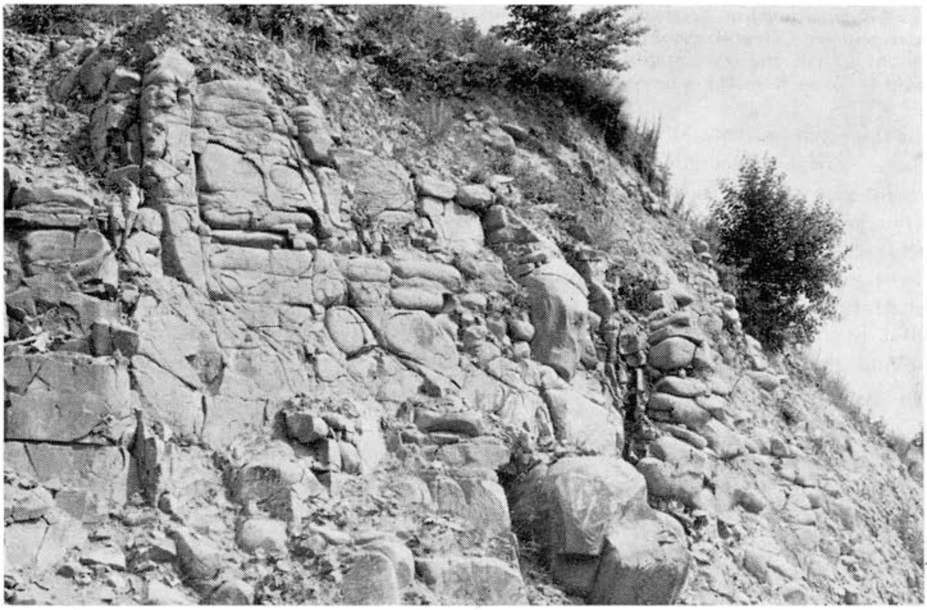


Fig. 19. Spheroidal weathering occuring, as illustrated, in the remnants of the lower parts of the Neogene crust of weathering after exposure in the quarry wall after several seasons. The quarry is situated between the villages of Sása and Babiná (Central Slovakia).

and temperature changes. In the Pleistocene glacial periods this depth reached 2—4 m. At present the depth of intense weathering is 1—2 m. As the Neogene crusts of weathering were mostly removed at the end of the Pliocene and during the Pleistocene, the Quaternary forms of eluviae dominate in the present relief of neovolcanites. Their thickness, however, dependently upon the energy of weathering agents related to relief, especially on the valley slopes, is reduced by the erosion processes.

Conclusions

Hydratation and hydrolysis as well as volume changes during the temperature and moisture changes are the most important processes of andesite weathering. The influence of the growth of crystals, mainly ice also are important in certain cases. These various processes intensely influence the engineering properties of the andesite. These changes can macroscopically be judged in their initial phases only by a professional geologist.

For practical aims it was necessary to prepare criteria for the judgement of the weathering grade and to designate suitable indicators of the weathering rate with the possibility of their quantitative interpretation. The analysis of the weathering processes and the test results of physical properties showed that for andesites the most suitable indicators of the weathering grade are the dry density, saturation moisture content and ultrasonic pulse velocity. These physical quantities show good correlation relationships with engineering properties of andesite. The development, thickness, and extent of weathered crust are influenced by physical and chemical weathering processes that characterize various geological periods.

The understanding of regional processes of development of weathered crusts is of great importance for the engineering geological investigation. This is of primary importance in the early phasse of such investigation. It has been shown that in the area of the Central Slovakian neovolcanites two fundamental types of crusts of weathering developed. These are the remnants of thick (up to several tens of meters) crusts of weathering with predominantly chemically decomposed andesites which formed during the Neogene and the more spread crust of weathering with predominantly mechanically disintegrated andesites to a depth of 2—4 m formed during the Quaternary. Their regional extension can be followed on the basis of analysis of the geomorphological development of the territory.

Translated by E. BLEHO.

REFERENCES

BLOCH, A. M., 1969: Struktura vody i geologičeskije processy. Moskva, Izdat. Nedra, 162 p.

CLARK, S. P. Jr., 1966: Handbook of physical constants. The Geol. Soc. of America, Inc. Memoir 97, New York, 562 p.

CORTE, A. E., 1969: Geocrynology and Engineering. Rev. Eng. Geol. II. (New York), p. 109—183.

ČERNJACHOVSKIJ, A. G., 1968: Nekotoryje voprosy fyzičeskogo i fyziko-chimičeskogo vyvetrivanija gornych porod. Kora vyvetrivanija. Vyp. 10, (Moskva), p. 18—29.

KUZNECOV, V. D., 1953: Kristally i kristallizacija. Moskva, Gostechizdat, 411 p.

MAZÚR, E. a kol., 1962: Vysvetlivky k prehľadnej geologickej mape ČSR 1 : 200 000, list Zvolen, (Bratislava), p. 101—110.

NEŠVARA, J., ONDRÁŠIK, R., 1975: Poruchy ochrannej vrstvy z netriedeného kameňa hrádzí Podvihorlatskej nádrže. Acta geologica et geographica Univ. Comenianae, (Bratislava), in press.

ONDRÁŠIK, R., 1968: Inžiniersko - geologický výskum kôry zvetrávania skalných hornín na Slovensku. Acta geol. et geograph. Univ. Com. (Bratislava), p. 5—24.

PRIKLONSKIJ, V. A., 1955: Gruntovedenije. Moskva, Gosgeolizdat, 430 p.

ROMM, J. S., 1966: Piltracionnyje svojstva treščinovatych gornych porod. Moskva, Izdat. Nedra, 278 p.

ROTH, E. S., 1965: Temperature and water content as factor in desert weathering. Journal of Geology 73/3, (Chicago), p. 454—469.

SERGEJEV, J. M., 1959: Gruntovedenije. Moskva, Univ. Izdat., 333 p.

Review by M. MATULA

ОБЗОР ГЕОХИМИЧЕСКОГО ИССЛЕДОВАНИЯ ОСАДОЧНЫХ ОБРАЗОВАНИЙ В ОБЛАСТИ ЗАПАДНЫХ КАРПАТ

В области Западных Карпат геохимические исследования осадочных образований проводились разными институтами и касались разных типов пород. Минералогическо-геохимическое исследование глинистых отложений опирающиеся на оценку содержания микроэлементов в горных породах более молодых толщ проводил доц. И. Краус канд. наук (Кафедра полезных ископаемых Естественного факультета Университета имени Я. А. Коменского), учитывая также зависимости областей ресурсов, минерального состава и характера среды осадконакоп-