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THE DEVELOPMENT OF CRYOPEDOLOGY IN CZECHOSLOVAKIA *

Abstract

In the area of Czechoslovakia which was during the maximum Pleistocene glaciation situated in the foreground of the ice-sheet, some periglacial soil-structures are preserved. Already during the first decades of this century, these phenomena were discussed in the Czechoslovakian literature, but their periglacial origin was recognized much later. Until quite recently, investigations in Czechoslovakia deal mainly with fossil structures. During the last years, research work turned to present-day phenomena occurring in high mountain regions. The effects of frost action, which are known from the study of fossil forms, require further investigations that are also of importance in other branches of Quaternary geology, and for practical purposes (agriculture, constructions etc). The importance of cryopedology, especially of applied cryopedology, has only now been duly appreciated.

In Czechoslovakia, observations concerning cryopedology are of fairly recent date since they appear nearly a whole century later than the earliest reports from this field in the world literature. And so, in 1770 Pernetty recognized a certain system in the arrangement of the boulders on the Falkland Islands but ignored the cause of its formation, and in 1837 von Baer gave the first description of polygonal soils without being able to explain their origin. In the geological literature dealing with some areas in Bohemia, appears in 1896 a section drawn by J. Jahn to supplement his paper: „Basalttuf-brekccie mit

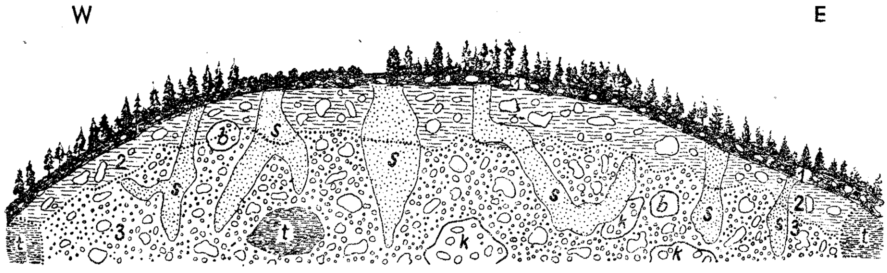

Fig. 1. Section of an exposure near Semtín (district of Pardubice), drawn by J. J. Jahn in 1896

1. uppermost humous-sandy layer (20—30 cm.) with numerous quartz pebbles; 2. upper clayey layer (50—75 cm.) with tuffitic breccia; 3. lower (1—2 m.) clayey layer with tuffitic breccia; s. wedges filled with fine-grained loose sand; b. compact basalt; t. opuka-Pläner marl; k. clayey calcareous waste from basaltic tuffs

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silurischen Fossilien in Ostböhmen"; however, this author also failed to give any correct explanation of the problem. The section is from an exposure at Semtín, NW of Pardubice (fig. 1). The clayey horizons with tuffitic breccia exhibit an abundant occurrence of pockets filled with fine-grained, brown, loose sand; these pockets the author calls *Säcke*. To-day, being in possession of comparative material, we can see that Jahn's section, although not too accurately elaborated, refers to various forms of Pleistocene ice-wedges filled with eolian sand from the Elbe terraces.

Later, in 1900, appeared Č. Zahálka's well-known paper: „O průlinách diluviálních v Čechách" (*77*) where the author develops an interesting explanation of the occurrence, in Cretaceous marls, of wedge-like depressions filled with sandy material (fig. 2). He compares these wedge-like forms which he calls *průliny*, to the grooves appearing in karst regions on bare, inclined surfaces. The walls of one of the wedges discovered by him in the Roudnice region exhibit an interesting pattern being as if paved with flat-lying slabs of marl. This fact, Č. Zahálka explains as follows: „. . . They were brought into this position by running water. And just because they are not horizontal but oblique to vertical, the water seeping through from above was flowing off and penetrating downward into the adjacent, very permeable sand, whereas the plates were more resistant to the disturbing action of water. Soon after their dilluvial formation, these *průliny* were filled with dilluvial sand. Had this occurred later, the flanks of the *průliny* would have collapsed under the action of weathering processes". That Zahálka's *průliny* might be ice-wedges, was a possibility that remained for a long time unremarked in the literature. This mainly because of the uncha-

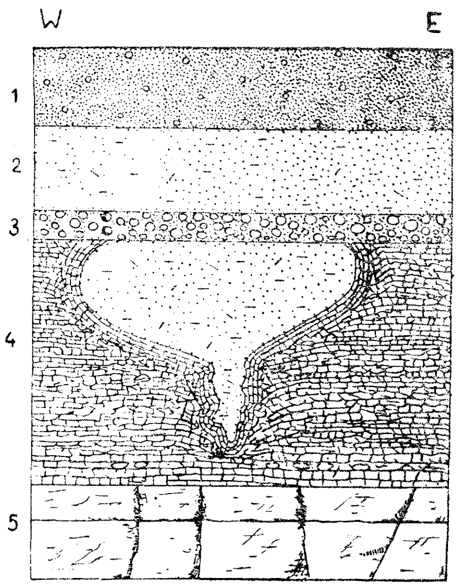

Fig. 2. A *prulina* (from the district of Roudnice) explained by Č. Zahálka (1900) as erosion trench

1. a humous-sandy layer; 2. blown sand with fragments of calcareous marl; 3. gravel layer; 4. cretaceous calcareous marl; 5. cretaceous marly limestones; filling of the wedge: blown sand with fragments of calcareous marl

racteristic bend of the layers in the direction of the wedge-filling instead of their up-thrust under the pressure of the adjacent material. To-day, however, when ice-wedges showing no up-thrust of the adjacent layers and also many exposures with ice-wedges in the area described by Zahálka are known from the literature, these structures can be no longer excluded from the type of forms produced by cryoturbation.

Another observation recorded in the earlier literature refers also to wedge-like structures. It appears in the remarkable explanatory discussion by C. Purkyně in his paper „Das Pleistocaen bei Pilsen", published in 1904, in which several profiles of wedge-like structures are described (*48*).

Still later, in 1912, R. Sokol published a paper (*65*) on the terraces of the middle Elbe, presenting an interesting section of the sandpit north of Velenka with wedge-like tongues of pebbly gravel. The formation of these wedges, the author attributes to „.... a powerful water current that disturbed the previously accumulated sandy layers and began to shift them and filling them at the same time with gravel from above" (*65*). To-day these tongues may be regarded as a system of wedges whose top portions were disturbed by solifluction or by cryoturbation, since they might as well be involutions (*zvířené půdy*) due to the disturbance of the sandy layers jointly with the thin impermeable layer of redeposited marls, by stresses operating within the zone of regelation. As the profile lacks accuracy of design and does not contain details that would permit to draw any inferences as to the action of the stresses or of the rotational movement, no precise conclusions can be derived from this section.

Likewise, L. Urbánek presented in his paper „Kolínsko a Kouřímsko", published in 1933, several profiles of wedge-like structures in sands and gravels but he also did not attribute them to frost action (*70*). Quite a number of similar reports can be found in the Czech literature. Let us, however, pass on to those contributions in which Pleistocene phenomena are, for the first time, in our country spoken of in terms of frost produced soil structures i. e. of structures having originated in periglacial climate and to the papers containing descriptions of present-day soil-forms.

The first observations concerning frost-produced phenomena, supplemented by some terms hitherto unknown in the Czech literature were reported in 1937 when B. Müller (*34*) described from the vicinity of the Liberec reservoir needle-ice (*jehlovitý led*) containing ice-needles up to 8 cm in height, which he called *Faserpelz*. This author was the first who introduced into the Czech literature the names of Low, Gripp, Grahmann, Dücker a. o. Being acquainted with several works by these writers, he tried, although somewhat incoherently, to compare present-day frost action in our country with present-day frost action and ice-structures in sub-Polar regions or with fossil phenomena in the earlier periglacial zone.

A correct recognition of frost-produced fossil structures (apart from observations collected in mountaineous areas — see e. g. Högbom, *11*; R. Sokol, *66*; C. Schott, *54* a. o.) was not achieved until the years 1940—43. Research-work was then chiefly conducted by H. R. Gärtner and R. Hundt, who were particularly engaged in the study of fossil involutions and ice-wedges occurring in western Bohemia.

H. R. Gärtner (*8*, *9*) gave a fairly detailed description of some involutions and funnel-like open wedges from the dale of Cheb. He regards these wedges as the effect of tectonic subsidence, but at the same time thinks them somewhat reminiscent in form of the ice-wedges described in 1936 by G. Selzer and W. Soergel. As evidence against their being ice-wedges he cites the inward bend of the gravelly and sandy layers, taking for granted that the marginal part of ice-wedges must always be up-thrust. The considerable degree to which the Cheb region is tectonically disturbed induced the writer to attribute the origin of these structures not to frost but to tectonic causes.

In the years 1941—42, E. Schönhals conducted research work in the area of Czechoslovakia and published in 1943 a report entitled „Diluviale Eiskeilfüllungen und andere Bodenfrosterscheinungen in Böhmen und Mähren" (*55*) which again refers to ice-wedges and involutions (*zvířené půdy*).

In 1941, 1942 and the following years experts proceded under the sponsorship of the „Institute for Soil Research in Bohemia and Moravia" to a basic mapping of the westernmost part of the Bohemio-Moravian Upland crystallinicum in the regions of Sedlčany and Říčany. In the course of this enterprise V. Ambrož (*2*) and Z. Roth (*50*, *51*) established the occurrence of some peculiar periglacial phenomena hitherto unknown in Czechoslovakia. In the Jevany Forest they found some embryonic cirques (*embryonální kary*), pseudo-moraines and varps or varp-steps (*varpové stupně*), as well as some embryonic cirques in the district of Sedlčany (fig. 3). Z. Roth believes these cirques to be some special instance of Pleistocene rubble (*skalní moří*) whose sliding was facilitated by ground-ice. In addition to the problem of passive moraines — which the author together with J. Kunský had opportunity to observe in Iceland — he deals with the question of frost-action upon rocks. V. Ambrož and Z. Roth cite many examples from Alpine, Polar and sub-Polar regions and introduce into the Czech literature some terms and concepts of international connotation which they sometimes replace by suitable translations. For example such terms as *Blockströme* or *Erdgletscher* Z. Roth translates into our language as *kamenné proudy* (boulder streams). For *stone-river* he uses the term

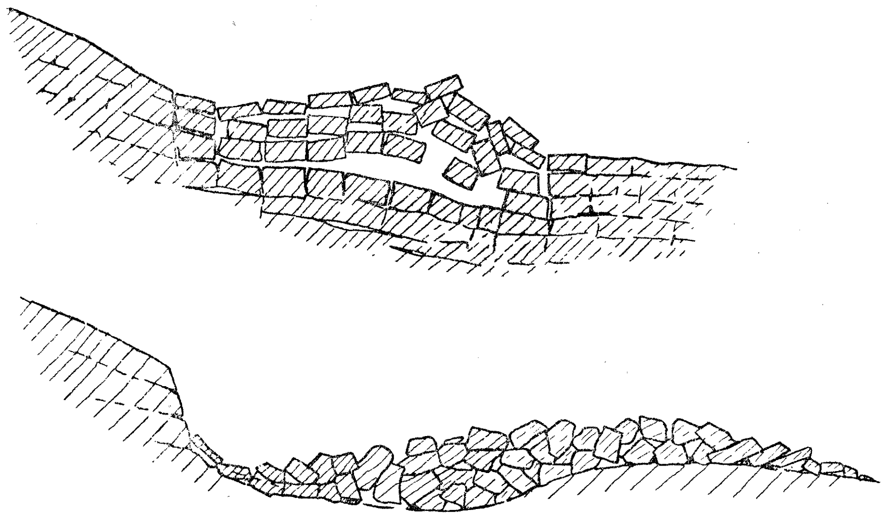

Fig. 3. A diagram of the origin of a block-stream and of its headwater cirque. Interstitial water contained the fissures of the rock interstitial ice of considerable thickness (upper figure). In the headwater a mound is produced which, when thawing creeps downhill as a boulderstream. The detachment area froms a cirque (Z. Roth, 1944)

kamenná řeka, introducing also into the Czech literature Sumgin's term *active layer* (*účinná vrstva*) to designate the subsurficial layer of permafrost. Capp's *rock-glaciers* he refers to as *skalní ledovce* and Högbom's *Spaltenfrost*, as *puklinové námrazy* (interstitial ice).

The fact that Czech geologists became acquainted with the foreign literature on fossil frost phenomena together with the results of their own intensified and more accurate field work contributed to a further advancement of cryopedology in Czechoslovakia. In 1943 appeared the first papers written by Czech geologists that can be said to differ from the earlier publications by a more thorough treatment of the problem and greater accuracy. These works brought some observations that were entirely new in the Czech literature on Quaternary geology (fig. 4).

And so, K. Žebera (*86*) was the first to recognize the presence of Pleistocene polygonal soils in the area of Buštěhrad, Q. Záruba (*80*) studied a number of fossil frost forms (fig. 5) in Prague and its vicinity, J. Kunský (*21*) discovered in southern Bohemia the first ice-wedges in the alluvial deposits of the crystallinicum.

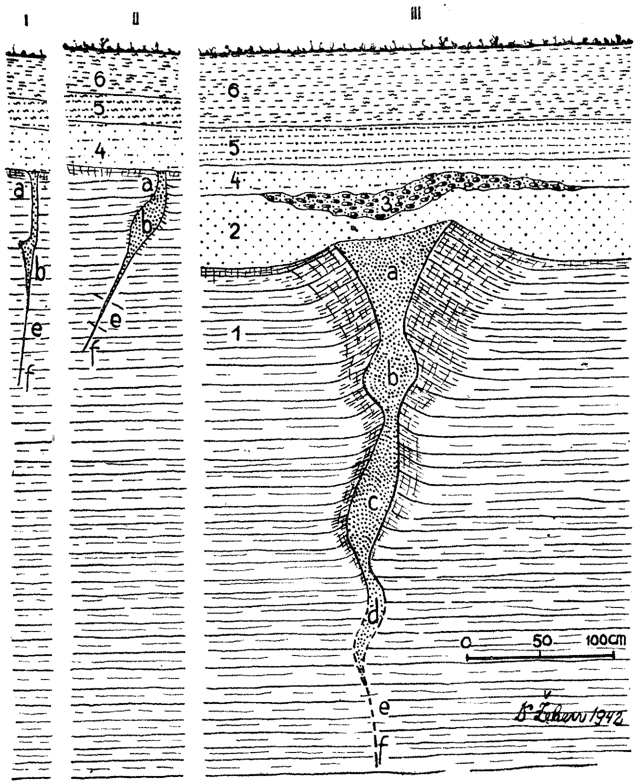

Fig. 4. Cross section through a frost fissure in the vicinity of Přívory in the district of Všetaty (K. Žebera, 1943)

1. cretaceous opuka-Pläner with a frost fissure filled with calcareous blown sand (a, b, c, d); 2. calcareous blown sand with opuka-Pläner debris (W I); 3. lens filled with material of rather resistant siliceous marls (W I/W II); 4. calcareous sandy blown loam (W II); 5—6. degraded black earth formed upon calcareous sandy loam

These developments in cryopedology during the years 1939—45 were due not only to the description of new exposures and to the explanation of new soil-structures but also to the abundant quotations from the foreign literature that was heretofore unknown in Czechoslovakia. We became familiar with the names of G. Andersson, the originator of the term *solifluction*, of B. Högbom, known for his classic work on present-day frost action in sub-Polar regions, as well as with the papers by P. Kessler who studied fossil soil structures on a wide scale. Quite as numerous were also references to Leffingwell who was the first to describe present-day frost cracks in Alaska, further to W. Meinardus, K. Gripp, H. Poser, A. Dücker, W. Soergel, F. E. Zeuner, A. I. Moskvitin, M. J. Sumgin, W. Łoziński and many others among whom also C. Purkyně, Č. Zahálka, R. Sokol a.o.

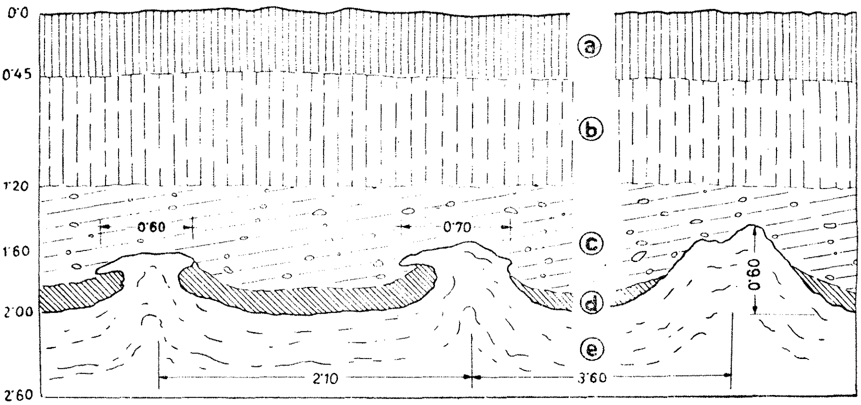

Fig. 5. Section showing Cretaceous clays displaced by frost, which forms mounds on the old surface of the Pleistocene tundra (Q. Záruba, 1943)

a. Holocene black earth; b. the younger loess; c. lower loess with fragments of opuka-Pläner; d. fossil black earth, remnant of the lowest loess; e. yellowish gray Cretaceous marls (zone IIIa)

Since 1945 investigations focussed essentially on the search of new localities showing ice-wedges, solifluction and other similar fossil structures. B. Zahálka (*76*) described from the Podřipsko area numerous wedges widely varying in form, and Q. Záruba — some wedge-like forms from the Turnov district (*83*). Later, with the development of studies, some more complicated profiles were investigated as can be seen from the paper by K. Žebera (*87*) in which the author gives closer and more cereful attention to the interrelationship of eolian accumulation and tundra phenomena. K. Žebera sets forth the interesting view that within the Pleistocene periglacial zone, ice-wedges, polygons and frost-kettles formed predominantly in loess with a shallow ground-water level and a compact bed-rock or else in clayey grounds and rocks. Owing to the constantly repeated process of freezing, they gradually changed into soil-structures folded by frost action (*půdy mrazem prohnětené*) which, on the slopes, passed into soliflual soils. K. Žebera also mentions so-called moving sands (*bludné písci*) that

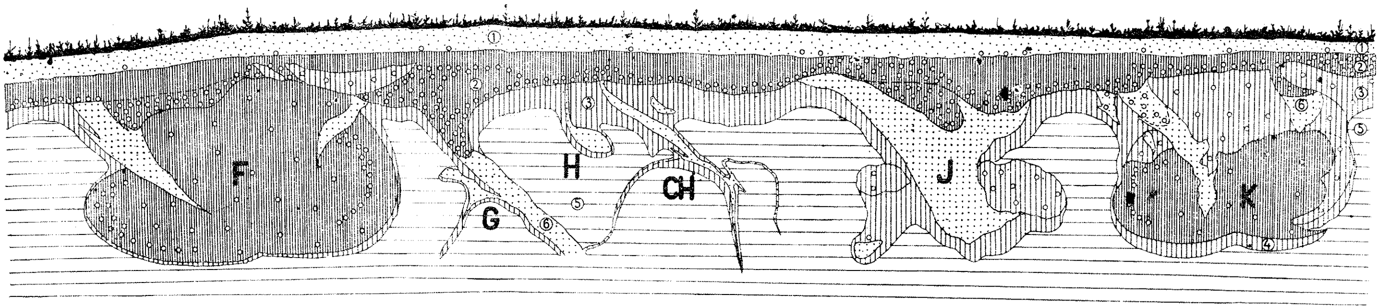

Fig. 6. Pleistocene ice-wedges and kettles in Cretaceous marls near Pardubice (part of the section) - K. Žebera, 1949

1. humous-loamy sand; 2. loamy-clayey gravel and sand (horizon B_1); 3. gravelly clay (horizon B_2); 4. spotted clay (decalcified cretaceous marl, horizon B_2); 5. spotted cretaceous Upper Tortonian marls; 6. eolian loamy sand, filling the ice-wedges; 7. erratic sands of eolian origin; F. the typical stage of a frost-kettle with two subsequent ice-wedges; G. the mature stage of an ice-wedge; H. an ice-wedge; CH. an ice-wedge; I. erratic sand; J. the initial stage of a frost--kettle; K. a typical frost-kettle with three subsequent ice-wedges

constitute part of the wedge filling and were, without any resistance, pressed out of their parent wedge (fig. 6). These sands may be compared to the so-called injections, referred to in the foreign literature as *sols injectés.*

All these studies, save those with a technical approach to the problem were not directly interested in its solution from a broader view-point including cryopedologic investigations into the scope of studies on Quaternary geology. It was not until 1952, in the work by M. Mazálek, K. Žebera, K. Zázvorka and V. Ložek on „The Mousterian settlements with lydite and quartz industry on the Lydite Ridge in Lobkovice" (*32*) i.e. in a paper dealing with archeological problems that we find besides geological, osteological, malacozoological and palynological investigations also a number of observations from the field of cryopedology. Owing to the results of cryopedologic research, the Pleistocene settlement in this locality was correlated with the interstadial Riss I—Riss II.

Apart from their stratigraphic significance, periglacial phenomena are also of importance as regards technical and agricultural purposes. On the basis of his investigations in the Elbe region, K. Žebera (*87*) holds that the sandy filling of fossil frost structures in clayey rocks, serve to a certain extend as reservoirs of ground-water. Q. Záruba (*80, 81*) discusses from a geotechnical view-point, frost phenomena occurring in the surroundings of Prague. V. Roth (*49*) observed at Vysočany the displacement of ground beneath basements by Pleistocene ice-wedges, and K. Žebera (*8,*) derived from his investigations in the Mělnik region, the conclusion that in hard rocks, fissures filled with eolian sand act as a drainage system. Descriptions of present-day frost action upon the soil appear comparatively earlier in the technical literature — chiefly in the one dealing with problems of construction — that the discussion of frost phenomena, whether modern or fossil, in the geological literature on the Quaternary. This was mainly due to the urgency of practical requirements imposed by the destruction of roads, buildings etc. In order to prevent further destructions, several solutions were suggested with reference to the foreign literature, and numerous tests were made both in the laboratory and in the field.

As far back as 1932, Q. Záruba (*79*) in his paper „Vyzkumné prace geologické v inženýrském stavitelství" (geological research in engineering) in which he chiefly refers to the work of Taber, devoted a special chapter to the effects of freezing and thawing on the soil surface. In 1937, A. Myslivec investigated the influence of freezing in connection with road-construction (*35*). Z. Schwarz published in

1942 a paper (*57*) on the action of frost upon the state of roads during the winter 1939—40, and Q. Záruba (*82*) — on the importance of periglacial rock-weathering and solifluction with regard to the basements of buildings.

The work of L. Ježek (*14*) published among the reports of the Public Technical Service represents an important contribution to the solution of the problems, whether theoretical or practical, arising in connection with the effects of freezing upon the soils. The author gives special attention to the formation, in the soil, of heterogeneous ice, as well as to the freezing capacity of the ground, to its viscosity and permeability. Ježek was the first in our literature to present a detailed discussion of Cassagrande's criterion, that serves to determine whether the ground is or is not susceptible of freezing i. e. whether the ice that is likely to form in it will be homo- or heterogeneous.

In Moravia-Silesia, cryopedological studies developed along quite different lines, being also considerably retarded as compared to their development in Bohemia. However, it is worth noting that as far back as 1924 K. Absolon (*1*) in his account of the first year of excavation works on the dilluvial stand of mammoth hunters at Dolní Věstonice described frost-caused disturbances of the layers. Unless these are mere fissures seperating masses of landslide material, K. Absolon must be regarded as the first Czech scholar who discovered, described and presented periglacial ice-structures in pulverulent sediments. According to Žebera, the presence of ice-wedges in the stand at Dolní Věstonice is quite possible.

We find in the literature some reports from Moravia referring to phenomena reminiscent of the fissures (*průliny*) described by Zahálka in 1900 (*77*). For example, V. Kalabis (*15*) observed in regions of Olomouc and Prostějov the penetration of Pleistocene sediments into Neogene sands.

In Moravia and Silesia, fossil periglacial structures were not studied until after World War II. One of the most interesting contributions is the paper by M. Vašíček (*72*) on Pleistocene periglacial disturbances in the Miocene sediments at Sudice and Muglínov. Apart from a general survey of the Czech as well as the foreign literature, the author gives a detailed description of the origin of ice-wedges and of their filling (fig. 7).

Entirely different from all the publications enumerated above is the one by J. Pelíšek (*38*) in which the writer attributes the formation of wedges to drought-produced cracks, that eventually led to the formation of ice-wedges. Quite recently, appeared also a paper by

J. Kunský (*24*), reporting the occurrence of ice-wedges in the Venušina volcano at Bruntál and containing descriptions of some ice-wedges in volcanic deposits, filled with finer material.

Only in profiles can periglacial soil structures be studied in Czechoslovakia, the area being recovered with a widespread, thick mantle of eolian formation, planed by periglacial solifluction and altered by weathering processes, and the surficial structures being destroyed by vegetation and human activities. Surficial soil-structures occur here mainly in altitudinal areas. As the mean annual temperature in the mountains of Czechoslovakia falls in some places below −1,5° C the conditions prevailing here are similar to those existing in sub-Polar

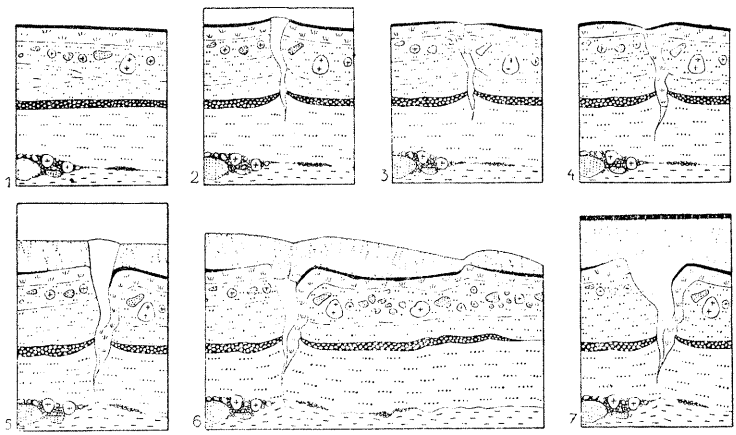

Fig. 7. The origin of a frost crack on the Jaklovec near Ostrava (M. Vašíček, 1946) 1. stage after the Lower Würm solifluction in the Würm interstadial; 2. Upper Würm — first cycle of the formation of the wedge (winters); 3. the same (summers); 4. Upper Würm — warmer intercycle of the formation of the wedge; 5. Upper Würm—second cycle of the formation of the wedge (winters) — the sedimentation of the loess raises the limit of the permafrost; 6. the same (summers) — solifluction; 7. the stage in a warmer period after the Upper Würm

regions or in Pleistocene periglacial areas. Therefore, it is not yet quite clear whether the ice-structures occurring here are fossil or modern in origin. I shall only briefly outline the results hitherto achieved by cryopedological research in the mountaineous regions of Czechoslovakia, without entering upon a separate discussion of those concerning present-day phenomena and those dealing with fossil phenomena.

At first, however, I wish to draw attention to a work, which is in the Czech literature the first containing descriptions and observations of contemporary frost-caused soil structures, although these observations were collected in area far remote from our country. I mean the geologico-geographic work by J. Kunský and Z. Roth (*26*) entitled „Tindfjallajökull", giving an account of the results of the first expedition of Czech scientists to Iceland in the summer 1936. In the area of the Tindjallajökull-glacier the authors studied the action of frost-weathering and solifluction. As a form particularly typical of this area they describe the so-called paved surfaces (*dlážděný povrch*), that are at present also known from our high mountains where similar structures arise during the short period of regelation.

Let us now turn again to the altitudinal areas where new localities with cryoturbate structures are being discovered with ever-increasing frequency. If we consult the list of Czech publications, we shall find that papers dealing with these phenomena are of much more recent date than those concerning fossil structures in lowland regions. It

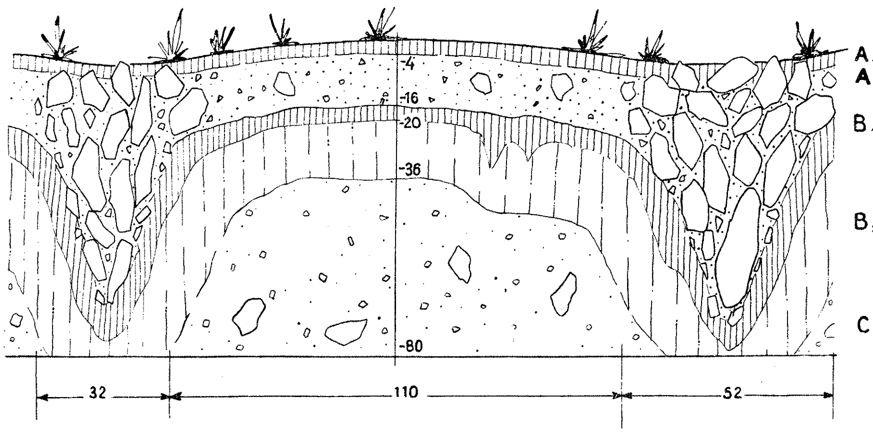

Fig. 8. Cross-section through the furrowed soil on the south-eastern slope of Mt. Luční hora (J. Kunský, Q. Záruba, 1950)

0— 4 cm. dark gray, strongly humous-peaty loam (A_0—A_1)
4—16 „ whitish gray, loamy-sandy earth with small fragments of quartzites (A_2)
16—20 „ blackish-brown, humous-loamy-sandy earth (B_1)
20—34 „ rusty-yellowish-brown loamy-sandy earth (B_2)
34—78 „ yellowish-brown loamy sand with fragments of quartzites (C)

is actually the reverse of what can be observed in the foreign literature especially in the German, the Polish, the Soviet, the Scandinavian and the North-American literature. Let us take for example the problem of structural soils in the Krkonoše (Giant Mountains) from where they were reported as early as in 1914 by B. Högbom in his classical work „Über die geologische Bedeutung des Frostes" and later, in 1929, by J. Gellert and A. Schüler (*10*), in 1931 by C. Schott (*54*), in 1933 by H. Ouvrier (*36*), in 1937 by A. Dücker (*7*) and J. Büdel (*4*), whereas in the Czech literature we find no mention of them until 1948 in the paper by J. Kunský in *Příroda v Krkonoších* (*23*) and, two years later, in the paper by J. Kunský and Q. Záruba (*27*) „Periglaciální strukturní půdy v Krkonoších". The authors describe these phenomena by reference to earlier publications and to their own results obtained by digging through the centers of the structures, a procedure that permitted to establish the presence of polygonal and furrowed soils (*polygonální, brázděné půdy*) that were classified as fossil (fig. 8).

In the same year as the paper mentioned above appeared in our literature the work of the Pole W. Walczak (*74, 75*) from Wrocław „O strukturních půdách v Krkonoších". Quite independently of the existing literature, basing his inferences merely upon his own observations this author defines stone-rings as modern forms.

However, structural soils were not the only forms that were recognized and observed in our mountains. Other frost-caused phenomena were investigated as well. And so in the early literature one can find remarks on rubble-fields and, in a general way, on frost-caused disintegration of compact rocks. From B. Högbom's fundamental work (*11*) we know of the occurrence of these forms in the Krkonoše. In 1917 they were also described by Sokol (*66*) from the Czesky Les. As far back as this date does Sokol mention stones produced by frost action and emphasizes the concept of sub-glacial solifluction with the meaning given the term by Andersson; he mentions also rubble-fields.

Following Högbom, Andersson, Passarge, Łoziński and Salomon he defines the phenomena described as periglacial facies of mechanical weathering having originated in the Ice Age (dilluvium). Later, Schott in his paper (*54*) cites several localities with rubble-fields. By the majority of authors, these forms are regarded as fossil. The writer also refers to rubble-fields occurring in the Hrubý Jeseník, where quite recently M. Prosová (*45, 46*) during her investigations of periglacial phenomena established, in the summit portion, the presence of new localities with polygonal soils. From the same region, Petránek (*43*) reports the occurrence of the interesting periglacial phenomenon called rock-glacier (*skalní ledovec*). Petránek is the first author who mentioned this phenomenon in our literature.

Let us still, for the sake of completeness, say a word about the state of cryopedologic research in the high mountains of Slovakia, which constitute that part of our country where frost-action is most intensive. During recent years, periglacial structures were likewise discovered in lower regions. Reports from altitudinal areas did not appear until 1950 (the first paper on thufurs and garland soils in the Bělske Tatry, by J. Sekyra, *58*). Until that date, apart from the problem of glaciation, no attention had been given to these mountain areas from the view-point of cryopedology. The occurrence of amorphous solifluction, polygonal soils, frost cracks and other highly interesting forms was reported from the Tatra region itself and from high mountain regions in the West Carpathians, the Vysoké, Bělské, Liptovské and Nízké Tatras or on the Babia Góra. The majority of these forms are believed to be modern. These areas have been so far described by M. Lukniš (*30*), J. Pelíšek (*39, 40*), J. Petránek (*42*) and J. Sekyra (*58—61*).

In 1954, J. Ksandr gave a detailed account of the cryopedologic investigations carried out in the Tatra National Park (*18*). I do not intend to discuss this problem, because the publications relative to mountain regions having appeared during the very last years are easily available (these publications are enumerated in the bibliography).

If we examine the list of the lates publications on the investigation of soil structures, whether modern or fossil, we can see at once that the development of these studies in Czechoslovakia was not so rapid as in other countries. The existence of a considerable number of localities displaying cryoturbate phenomena has undoubtedly exerted a powerful influence upon the development of cryopedology, as it is the case in those countries lying north of our Republic that were invaded by Pleistocene glaciation as well as in the countries with extensive high mountains regions, not to speak of the northern countries. Our studies which were so far based mainly upon the results obtained by Leffingwell, Andersson, Högbom, Troll and many others, will be also in the future supported by the knowledge derived from the achievements and views of those research workers whose experience comes from the study of typical, frost-caused forms, fossil as well as modern, that constitute the best source of sound knowledge. Therefore, the investigation of intensive frost action and of present-day soil structures can not be underestimated. We know from experience that our geologists have had so far only a few rare opportunities to carry on research work in sub-Polar, Polar or typical high mountain regions. We must therefore try to broaden our knowledge in this field of study, by taking advantage of all the possibilities offered by our own country.

References

1. Absolon, K. — Výzkum diluviálni stanice lovců mamutů v Dolních Véstonicích na Pavlovských kopcích na Moravě (Investigations of a diluvial stand of mammoth-hunters at Dolní Věstonice on the Pavlovské hills in Moravia). *Pracovni zpráva za první rok 1924,* Brno.

2. Ambrož, V.—Periglaciálni zjevy u Jevan (Zusammenfassung: Periglaziale Erscheinungen bei Jevan). *Zprávy Geol. ústavu pro Čechy a Moravu*, 18, Praha 1943.
3. Andrusov, D. — Polygonálne pôdy na dne Tatranských plies (Polygonal soils on the bottom of Tatra-lakes). *Geol. sbor. SAV, 1954*, Bratislava 1955.
4. Büdel, J. — Eiszeitliche und rezente Verwitterung und Abtragung im ehemals nicht vereisten Teil Mitteleuropas. *Pet. Geogr. Mitt.*, Ergh. 229, Gotha 1937.
5. Chábera, S. — Kamenná moře jižních Čech (A boulder field in Southern Czechoslovakia). *Ochrana přírody*, 9, Praha 1954.
6. Chábera, S. — Periglaciální zjevy v jižních Čechách (summary: The periglacial phenomena in South Bohémia). *Rozpravy Českosl. Akad. Věd.*, 65, Praha 1955.
7. Dücker, A. — Über Strukturböden im Riesengebirge. Ein Beitrag zum Bodenfrost- und Lössproblem. *Ztschr. Deutsch. Geol. Ges.*, Bd. 89, 1937.
8. Gaertner, H. R. — Spuren junger Tektonik im Egerer Becken. *Berichte d. Reichstelle f. Bodenforsch.*, Jhg. 1941, Wien 1941.
9. Gaertner, H. R. — Brodelböden in der Gegend von Eger. *Berichte d. Reichsamts f. Bodenforsch.* Jhg. 1941, Wien 1941.
10. Gellert, J. F., Schüller, A. — Eiszeitböden im Riesengebirge. *Ztschr. Deutsch. Geol. Ges.*, Bd. 81, 1929.
11. Högbom, B. — Über die geologische Bedeutung des Frostes. *Bull. Geol. Instit. Upsala*, vol. 12, 1914.
12. Hundt, R. — Diluviale Eiskeile im Saazer Becken. *Ztschr. f. Geschiebeforsch. u. Flachslandgeol.*, 17, Leipzig 1941.
13. Jahn J. J. — Basalttuff-Breccie mit silurischen Fossilien in Ostböhmen. *Verhandl. d. k. k. Geol. Reichsanst.*, 16, Wien 1896.
14. Ježek. L. — Dnešní stav bádání o promrzání zemin (The state of present research on soil-freezing). *Zprávy veřejné služby technické*, Praha 1947.
15. Kalabis, V. — O železitých válcovitých tvarech a ostatních železitých sedimentech v neogénu okolí Olomouce a Prostějova (Ferruginous concretions and other ferruginous sediments in the Neogene around Olomouc and Prostějov). *Věstník Klubu přírodovědeckého v Prostějově*, 24, 1935.
16. Kettner, R. — Co je to soliflukce (What is solifluction). *Vesmír*, 28, Praha 1950.
17. Kettner, R. — Všeobecná geologie — díl II. a III (General geology — part II and III). Praha 1948, 1953.
18. Ksandr, J. — Mrazové půdní formy v Tatrách (summary: Frost soil forms in the Tatra). *Ochrana přírody*, 9, 10, Praha 1954, 1955.
19. Ksandr, J. — K výskytu a ochraně periglaciálních zjevů u Jevan (To the occurrence and protection of phenomena near Jevany). *Ochrana přírody*, 9, Praha 1954.
20. Kunský, J. — Hříčky polární přírody (The freaks of polar nature). *Naší přírodou*, 2, Praha 1939.
21. Kunský, J. — Fosilni zvětrávání v jižních Čechách (Fossil weathering in Southern Czechoslovakia). *Sborník Čs. Spol. Zeměp.*, 49, Praha 1944.
22. Kunský, J. — Mrazové klíny v jižních Čechách (Ice-wedges in Southern Czechoslovakia). *Sborník Čs. Spol. Zeměp.*, 50, Praha 1945.
23. Kunský, J. — Geomorfologický náčrt Krkonoš (A morphological sketch of the Krkonoše-Mountains). *Příroda v Krkonoších*, Praha 1948.
24. Kunský, J. — Ke geomorfologii žulového jádra nízkotatranského. Mrazové klíny na Venušině sopce ve Slezsku (summary: Contribution to the geomorphology of the granitic cores of the Tatra Mts. Ice-wedges on the Venušina Sopka in Silesia). *Rozpravy Čs. Akad. Věd.*, 64, Praha 1954.

25. Kunský, J., Král, V. — Zpráva o mapování pokryvných útvarů v oblasti Chabence v Nízkých Tatrách (Raports on the mapping of cover material in the area of Chabence in Low Tatra). *Zprávy ÚÚG o geologických výzkumech v r. 1952*, Praha 1952.

26. Kunský, J., Roth, Z. — Tindfjallajökull. *Rozpravy Čs. Akad. Věd.*, 50, Praha 1940.

27. Kunský, J., Záruba, Q. — Periglaciální strukturní půdy v Krkonoších (summary: The periglacial structural soils in the Giants Mountains). *Sborník Čs. Spol. Zeměp.*, 55, Praha 1950.

28. Lais, R. — Über den jüngeren Lösse Niederösterreich, Mähren und Böhmen. *Berichte der Naturforsch. Gesell. zu Freiburg i. Br.*, 41, Freiburg, 1951.

29. Louček, D. — Geomorfologie veléhorské oblasti Královy Holy v Nízkých Tatrách (summary: Geomorphology of the High Mountain Region of the Králova Hola in the Low Tatra). *Rozpravy Čs. Akad. Věd*, 64, Praha 1954.

30. Lukniš, M. — Príspevok k poznaniu foriem mrazového zvetrávania skal v Západných Karpatach (summary: Contribution to the knowledge of the forms of frost weathering of the rocks in the Western Carpathians). *Sborník Čs. Spol. Zeměp.*, 59, Praha 1954.

31. Macoun, J., Šibrava, V. — Výzkum kvartéru na Ostravsku (Investigations of the Quaternary in the region of Ostrava). *Přírod. sbor. Ostr. kraje*, 15, Opava 1954.

32. Mazálek, M., Zébera, K., Zázvorka, V., Ložek, V. — Moustérské sídliště s buližníkovou a křemennou industrií na buližníkovém hřbetu u Lobkovic — Brandýs n. Labem (résumé: Station moustérienne à industrie de lydienne et de quartz sur la croupe de lydienne près de Lobkovice, Brandýs nad Labem. *Anthropozoikum*, 2, Praha 1952.

33. Mazúr, E. — K formám rozpadu hrebeňov v Malej Fatre (Zusammenfassung: Zu den Zerfallsformen der Gebirgskäme in der Kleinen Fatra). *Geografický časopis*, 6, Bratislava 1954.

34. Müller, B. — Brodelboden an der Reichenberger Talsperre. *Firgenwald*, 10, Reichenberg (Liberec) 1937.

35. Myslivec, A. — Vliv promrzání zemin na stavby silniční (résumé: Influence du gel des terrains sur la construction des routes). *Zprávy veřejné služby technické*, (1937), Praha 1938.

36. Ouvrier, H. — Beiträge zur Morphologie d. Hoh. Riesengebirge. *Veröff. Schles.*, 17, Wrocław 1933.

37. Pelíšek, J. — Kamenná moře na západní Moravě (A boulder-field in western Moravia). *Vesmír*, 31, Praha 1952.

38. Pelíšek, J. — Periglaciální zjevy ve spraších okolí Brna (summary: Periglacial phenomena in the loess of the Brno district). *Sborník Čs. Spol. Zeměp.*, 58, Praha 1953.

39. Pelíšek, J. — Tundrové půdy v jižní krasové oblasti Bělských Tater (Tundra-soils in the southern karst-area of the Tatry Bielskie). *Českoslov. Kras*, 6, Brno 1953.

40. Pelíšek, J. — Políčkovité a terasovité půdy ve Vysokých a Belánských Tatrách (summary: Polygonal and guirland soils of the High Tatra and Belanské Tatry Mountains in Czechoslovakia). *Geograficky časopis*, 5, Bratislava 1953.

41. Pelíšek, J. — Políčkovité půdy v oblasti Babie Hory — Orava (Soil-polygons on Mt. Babia — Orava). *Vesmír*, 33, Praha 1954.

42. Petránek, J. — Guirlandové půdy v ČSR (Garland soils in Czechoslovakia). *Vesmír* 31, Praha 1952.

43. Petránek, J. — Polygonální půdy v Jihoslovenském krasu (summary: Stone rings and pebble-covered pavements in the South Slovakian Karst). *Sborník Čs. Spol. Zeměp.*, 58, Praha 1953.
44. Petránek, J. — Skalní ledovec u Malé Morávky v Hrubém Jeseníku (summary: Rock-glacier of Malá Morávka). *Přírod. sbor. Ostr. kraje*, 14, Opava 1953.
45. Prosová, M. — Předběžná zpráva o polygonálních půdách ve Vysokém Jeseníku (A provisional notion on soil-polygons at the Vysoký Jeseník). *Přírod. sbor. Ostr. kraje*, 13, Opava 1952.
46. Prosová, M. — Studie o periglaciálních zjevech v Hrubém Jeseníku (Zusammenfassung: Studien über Periglazialerscheinungen im Altvatergebirge). *Přírod. sbor. Ostr. kraje*, 15, Opava 1954.
47. Prošek, F. — Výzkum jeskyně Dzeravé Skaly v Malých Karpatech (Investigation in the cave Dzeravá Skala in the Little Carpathians). *Archeologické rozhledy*, 3 Praha 1951.
48. Purkyně, C. — Das Pleistocaen (Diluvium) bei Pilsen. *Bull. Intern. Acad. Sci. de Boheme* (1904), Praha 1904.
49. Roth, V. — Porušení základové půdy pleistocenními mrazovými klíny ve Vysočanech (summary: Ground-disturbances caused by the Pleistocene ground-ice wedges in Prague-Vysočany). *Technický obzor*, 57, Praha 1949.
50. Roth, Z. — Stopy pleistocenního podnebí v oblasti středočeského krystalinika (Zusammenfassung: Spuren des Pleistozänen Klimas im Gebiete des Mittelböhmischen Kristalinikum). *Příroda*, 35, Brno 1943.
51. Roth, Z. — Skalní proudy, ledovcové kary a ledovce (Rock streams, glacial cirques and glaciers). *Rozpravy II. tř. Čs. Akad.*, 54, Praha 1944.
52. Roth, Z. — Základové půdy údolních přehrad jako výsledek pleistocenního podnebí (summary: The foundation ground of the dams in Czechoslovakia and in Western Europe as the result of the influence of the Quaternary climate and geological development). *Sborník Ústr. Úst. Geol.*, 21, Praha 1955.
53. Roth, Z., Hadač, E. — Vymrzávání balvanů (Frost-heaving of boulders). *Vesmír*, 25, Praha 1947.
54. Schott, C. — Die Blockmeere in den deutschen Mittelgebirgen. *Forsch. z. deutsch. Landes- und Volkskunde*, 29, Stuttgart 1931.
55. Schönhals, E. — Diluviale Eiskeilfüllungen und andere Bodenfrosterscheinungen in Böhmen und Mähren. *Berichte d. Reichsamts f. Bodenforschung*, Wien 1943.
56. Schönhals, E. — Über fossile Böden im nichtvereisten Gebiet. *Eiszeitalter u. Gegenwart*, Bd. 1, 1951.
57. Schwarz, Z. — Poznatky z účinků mrazů na našich silnicích v zimě r. 1939—40 (Frost-effects on our roads in winter 1939—40). *Zprávy veřejné služby technické*, 24, Praha 1942.
58. Sekyra, J. — Thufury a guirlandové půdy v Bělských Tatrách (summary: Thufur and garland soils in the Bělské Tatry). *Sborník Čs. Spol. Zeměp.*, 55, Praha 1950.
59. Sekyra, J. — Tundrové půdy v Československu (Tundra-soils in Czechoslovakia). *Ochrana přírody*, 7, Praha 1952.
60. Sekyra, J. — K otázce recentnosti strukturních půd (On the recent origin of structural-soils). *Věstník Ústř. Úst. Geol.*, 29, Praha 1954.
61. Sekyra, J. — Velehorský kras Bělských Tater (summary: The alpine karst in the Bělské Tatry). *Publikace Ústř. Úst. Geol.*, Praha 1954.
62. Sekyra, J. — K mrazovému klínu u Hranic; in: Žebera, K., Sekyra, J., Ambrož, V., Pokorný, M.: Zpráva o výzkumu čtvrtohorních pokryvných útvarů na Ost-

ravsku v r. 1953 (About an ice-wedge near Hranice). *Anthropozoikum*, 4, (1954), Praha 1955.

63. Sekyra, J. — Zpráva o kvartérně geologickém výzkumu v Železných horách (summary: Report on the Quaternary geological survey in the Železné hory). *Anthropozoikum*, 4, (1954), Praha 1955.
64. Sekyra, J. — Kryopedologická pozorování na jižních svazích Vysokých Tater v dubnu 1954 (summary: Cryopedological observations on the southern slopes of the Vysoké Tatry in april 1954). *Anthropozoikum*, 5, (1955), Praha 1956.
65. Sokol, R. — Tarasy středního Labe v Čechách (Terraces of the middle Labe in Czechoslovakia). *Rozpravy II. tř. Čs. Akad.*, 21, Praha 1912.
66. Sokol, R. — Česky les. Geologický průřez horstvem a předhořim — část I. (Bohémian Forest Mountains — A geological section through the mountains and the promontory — Part I). *Rozpravy Čs. Akad.*, 28, Praha 1917.
67. Spirhanzl, J. — Leďové výtvory na povrchu půdy a v půdě (Ice-buildning on the soil surface and in the soil). *Meteorologické zprávy*, 4, Praha 1950.
68. Stejskal, J. — Geologie dynamická (Dynamic geology). *Velký ilustr. přírodopis všech tři říší*, sv. 8, Praha 1949.
69. Šibrava, V., Macoun, J. — Nálezy mrazových klínů na Hlučínsku (The findnigs of ice-wedges in Hlučín-Land). *Přírod. sbor. Ostr. kraje*, 15, Opava 1955.
70. Urbánek, L. — Kolínsko a Kouřimsko — 5 Geologie (Kolínsko and Kouřimsko — 5 Geology). Nákladem učitelstva školního okresu kolínského, Kolín 1933.
71. Urbánek, L. — Vysvětlivky k přehledné mapě základových půd ČSR 1 : 75.000 — list Kolín 3954 (résumé: Notice explicative de la carte synoptique des formations superficielles...), Praha 1948.
72. Vašíček, M. — Pleistocenní poruchy v miocenních sedimentech u Sudic a Muglínova (Pleistocene disturbance of Miocene deposits near Sudice and Muglínov). *Věstník král. Čs. Spol. Nauk*, 1944, Praha 1946.
73. Veselý, J. — Příroda Československa, její vývoj a ochrana (Nature of Czechoslovakia, its developement and protection). Praha 1954.
74. Walczak, W. — Gleby strukturalne w Karkonoszach (Structural soils in Karkonosze Mountains). *Przegl. Geogr.*, t. 21, Warszawa 1948.
75. Walczak, W. — O strukturálních půdách v Krkonoších (Structural soils in Krkonoše Mountains). *Přírod. sbor. Ostr. kraje*, 11, Opava 1950.
76. Zahálka, B. — Plistocenní mrazové klíny na Podřipsku (résumé: Les fentes en coin pleistocenes des environs du Říp). *Věstnik Stain. Geol. Úst.*, 22, Praha 1947.
77. Zahálka, Č. — O průlinách diluviálních v Čechách (Zusammenfassung: Über die Diluvial-Karren in Böhmen). *Věstník kr. Čes. Spol. Nauk*, Praha 1900.
78. Zapletal, K. — Geologie předmosteckého diluvia (Zusammenfassung: Geologie des Předmoster Diluviums). *Práce z paleolit. odd. Mor. Zem. Musea*, 11, Brno 1929.
79. Záruba, Q. — Výzkumné práce geologické v inženýrském stavitelství (The geological investigations in civil engeneering). *Masarykova Akademie Práce*, č. 53, Praha 1932.
80. Záruba, Q. — Periglaciální zjevy v okolí Prahy (Periglacial phenomena in the environs of Praha). *Rozpr. II. tř. Čs. Akad.*, 53, Praha 1943.
81. Záruba, Q. — Nové pleistocenní profily z Čakovic (Zusammenfassung: Neue pleistozäne Profile von Tschakowitz bei Prag). *Věstník král. Čs. Spol. Nauk*, Praha 1944.
82. Záruba, Q. — Význam periglaciálního větrání hornin a soliflukce pro zakládání staveb (The importance of periglacial rock-weathering and solifluction to architecture). *Technický obzor*, 52, Praha 1944.

83. Záruba, Q. — Periglaciální zjevy na Turnovsku (summary: Periglacial phenomena in the Turnov Region). *Sborník Ústř. Úst. Geol.*, 19, Praha 1952.
84. Záruba, Q., Hromada, K. — Technicko-geologický rozbor území Kutné Hory (summary: Geologico-technical surveying of the town of Kutná Hora). *Geotechnika*, 9, Praha 1950.
85. Záruba, Q., Roth, Z. — Pleistocenní uloženiny na buližníkovém kamýku mezi Velení a Přezleticemi (summary: Pleistocene sediments in the lydite quarry near Přezletice). *Věstník Statn. Úst. Geol.*, 20, Praha 1946.
86. Žebera, K. — Pleistocenní mrazové pukliny a mnohoúhelníkové mrazové půdy v Čechách (Zusammenfassung: Pleistozäne Frostkeile und polygonale Frostböden in Böhmen). *Sborník Čs. Spol. Zeměp.*, 48, Praha 1943.
87. Žebera, K. — K současnému výzkumu kvartéru v oblasti Českého masivu (résumé: A propos de l'exploration actuelle des terrains quaternaires dans le domaine du Massif bohémien). *Sborník Statn. Geol. Úst.*, 16, Praha 1949.
88. Žebera, K. — Vysvětlivky k přehledné mapě základových půd ČSR, 1 : 75.000, list Pardubice-Hradec Králové 3955 (résumé: Noticę explicative de la carte synoptique des formations superficielles...) Praha 1952.
89. Žebera, K. — Čtvrtohorní zvětralinové pláště a pokryvné útvary ČSR, jejich vznik, skladba, stáří a význam (Quaternary mantle-rock and cover material in Czechoslovakia, their origin, structure, age and function). *Učební texty vys. škol. Universita Karlova*, Praha 1953.
90. Žebera, K. — Některé zajímavější výsledky výzkumu čtvrtohor v oblasti Českého masivu v roce 1951 (résumé: Quelques résultats intéressants des recherches faites en 1951 sur les terrains quaternaires dans le domaine du Massif Bohémien). *Anthropozoikum*, 3, 1953, Praha 1954.
91. Žebera, K. — Výsledky výzkumu kvartérních sedimentů v Předmostí u Přerova na Moravě (Zusammenfassung: Die Ergebnisse der Durchforschungen von quartären Sedimenten in Předmostí bei Přerov in Mähren im Jahre 1952). *Anthropozoikum*, 3, 1953, Praha 1954.
92. Žebera, K., Ložek, V. — Příčný řez buližníkovým hřbetem a musterienským sídlištěm u Lobkovic a jeho malakofauna (Crossection of a ridge of siliceous schist with traus of Mustierian settlement near Lobkovice and their malacofauna). *Anthropozoikum*, 3, 1953. Praha 1954.

photo by J. Sekyra

Pl. 1. Blocks of resistant weathering rocks stand out through congelifraction clearly visible. A crag, 10 m. high, in the summit part of the Králova Hola (1943 m.) in the Nízké Tatry Mts.

photo by J. Sekyra

Pl. 2. Thufurs in the Kopa saddle, 1770 m. above sea-level (Vysoké Tatry Mts.)

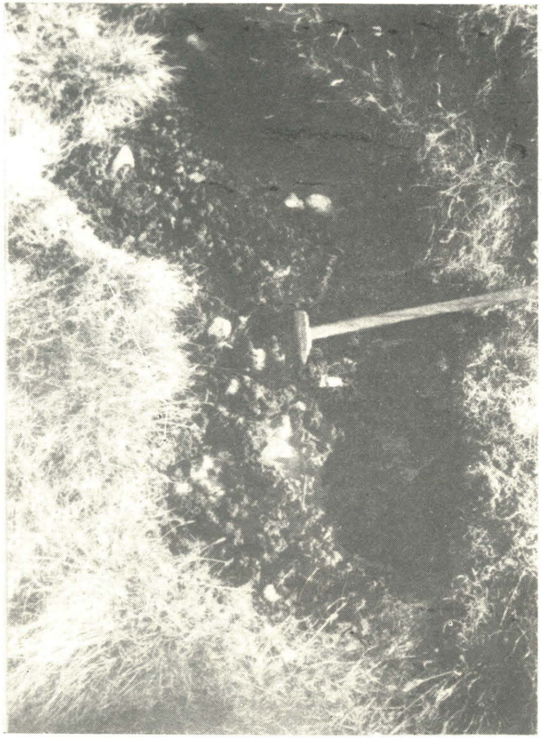

photo by J. Sekyra

Pl. 3. Turf cover worn by the action of the Pipkrake. Surroundings of the Téry's hut, 2050 m. above sea-level, in the valley Malá Studená Dolina in the Vysoké Tatry Mts.

photo by J. Sekyra

Pl. 4. Garland soils on the NE slope of the Bujačí Vrch (1950 m.) in the Bělské Tatry Mts.

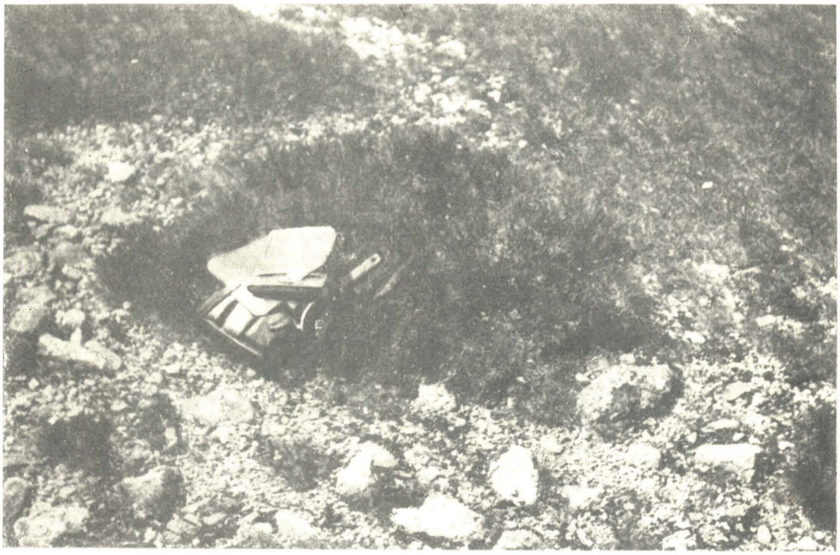

photo by J. Sekyra

Pl. 5. Structural soils in the saddle (1948 m.) south of the Velká Kopa in the Vysoké Tatry Mts.

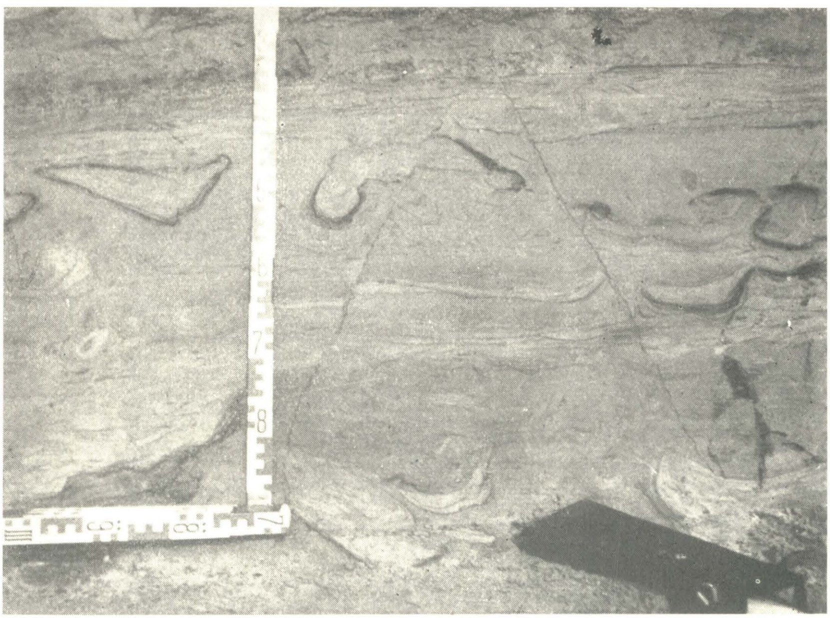

photo by J. Sekyra

Pl. 6. Cryoturbation in the fluvioglacial cryotectonically worn sediments, locality near Nový Jičín

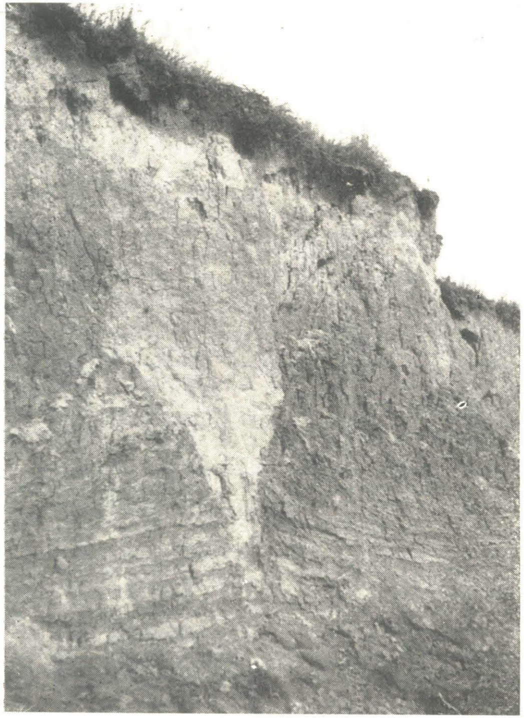

photo by J. Sekyra

Pl. 7. An ice-wedge, 225 cm. deep, in the old cover of loess loams in the Miocene sediments. The wedge is filled with the loess-like loam of the upper cover. In the lower part of the wedge calcareous loess is preserved. Hranice in Moravia

photo by J. Sekyra

Pl. 8. An ice-wedge in amphibolite shales filled with eolian sand. A locality near Týnec nad Labem.

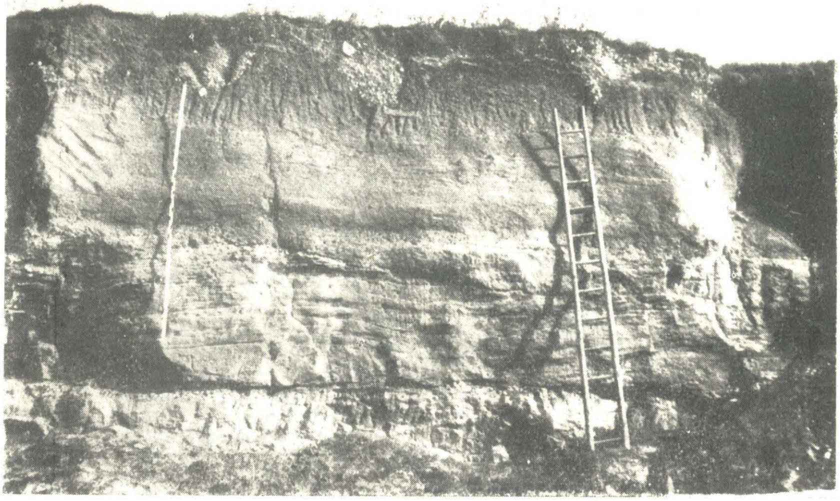

photo by J. Sekyra

Pl. 9. Ice-wedges and kettles in Cretaceous sandstones near Golčův Jenikov. The filling of the wedges consists of gravels and sand of high terraces. In the exposure, the fossil regelation zone is visible

photo by J. Sekyra

Pl. 10. A rectified skeletal solifluction horizon buried by blown sands. On the right hand side above the dark subsoil horizon a drift of the subrecent blown sand is visible. Sovoluská Lhota in the Železné Hory