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ГЕОЛОГИЈА - GÉOLOGIE

PROPOSALS FOR SUPPLEMENTING THE STRUCTURAL TERMINOLOGY OF FOLDED-NAPPE AND IMBRICATE-THRUST STRUCTURES

by

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The article includes structural problems connected to complex reverse faults. In accordance with kinematics and morphology of nappes and overthrusts, we suggest filling in the existing terms and introducing new ones which will determine, more precisely, structural characteristics of the reverse ruptures. Filling in is based on the results of structural exploration of alochthones autochthones, as well as characteristics of the overthrust planes.

Key words: nappe, overthrust, nappe-syncline (synclinorium), nappe-anticline (anticlinorium).

The history of the concepts of mass overthrusts, or nappes, has been set forth in detail by I. I. Belostotskiy (Belostotskiy, 1970) and G. D. Azhgirey (Azhgirey, 1977). Their publications contain sections on the morphology of nappes, in which the basic concepts of allochthon, autochthon, and the root, shield and frontal parts of a nappe, etc., are summarized and discussed.

These terms have entered thoroughly into the geological literature, become fixed in the consciousness of geologists, and are used successfully in practical geologic-survey operations. But the terminology of thrusts is at the present time inadequate. It does not reflect their variety, and fails to take into account the internal structure of allochthon and the form and character of the displacement planes bordering them.

In an article on the geology of the Alps, P. Termier (Termier, 1903) proposed that nappes of the first and second kind be distinguished. To the first category he assigned the nappes that were formed from strongly drawn out recumbent folds, and to the second those which arose in the further development of gently sloping overthrusts. This was one of the first attempts at a structural analysis of the mass overthrusts of the Alps.

J. Aubouin's idea of the suitability of distinguished tectonic nappes of the base and cover are worth considering. According to Aubouin, basal nappes are formed most com-

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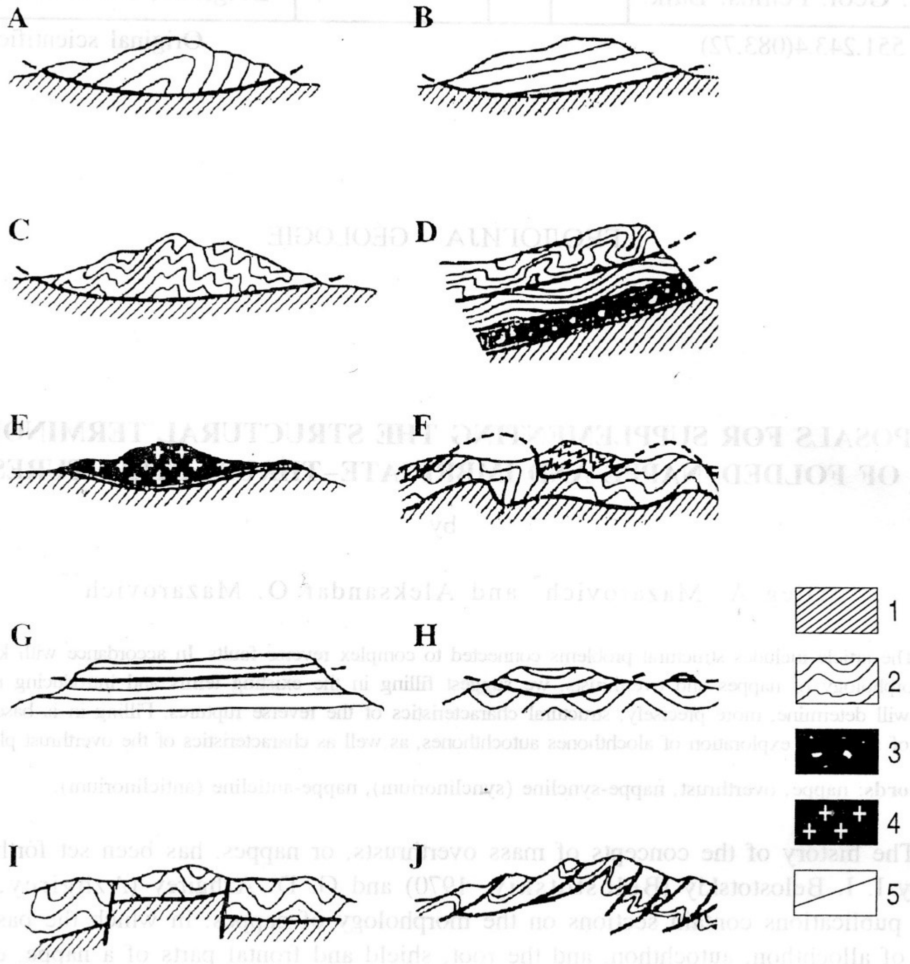

Fig. 1. Idealized diagrams of certain folded–nappe and imbricate–overthrust structure: A) nappe–anticline; B) nappe–homocline; C) nappe–anticlinorium; D) homocline of nappes or homoclinal packet of nappes consisting of three sheets; E) nappe–batholith; F) polyclinal packet of nappes; G) conformable nappe (in this case, nappe–anticline); H) disconformable nappe (in this case, nappe–syncline); I) post–nappe horst; J) squamanticlinorium (imbricate–overthrust anticlinorium); 1) autochthon, structure unspecified 2) stratiform rock series; 3) melange; 4) intrusive mass; 5) ruptural plane of displacement–surface of thrust sheets of mass overthrust, normal faults, listric reverse faults, or overthrusts. Zones of displacement planes of mass overthrusts are represented by shatter zones, zones of serpentinite or terrigenous melange, gypsiferous series, etc. Approximate scale of structures indicated in text.

Сл. 1. Идеализовани дијаграми извесних структура набране навлаке и краљушти: А) навлака–антиклинала; Б) навлака–хомоклинала; Ц) навлака-антиклиноријум; Д) хомоклинала навлака или хомоклинални пакет навлака од три дела; Е) навлака–батолит; Ф) поликлинални пакет навлака; Г) конкордатна навлака (у овом случају навлака-антиклинала); Х) дискордантна навлака (у овом случају дискордантна навлака–синклинала); И) пост–навлачни хорст; Ј) сквамантиклиноријум (краљушасти антиклиноријум); 1) аутохтон, неодређена структура; 2) серија стратиформних стена; 3) меланж; 4) интрузивна маса; 5) разломна раван померања–површина навлаке шаријажа, нормални расeди, криви реверсни раседи, или навлаке. Зоне равни кретања шаријажа представљене су здрузганим зонама, зонама серпентинита или теригеног меланжа, гипсоносним серијама итд. Приближна размера структура назначена у тексту.

monly from an interior (eugeosynclinal) uplift or, at any rate, from the rear inner part of the folded region; either the crystalline rocks of the basement complex or the rocks of the preceding geotectonic cycle are drawn into the enormous horizontal overthrusts. Cover nappe was his term for a torn–off sedimentary cover that had lost all connection with its normal substrate and was displaced within the sedimentary cover by another structural–facies zone. Aubouin says nothing about the thickness of the allochthon or its degree of conformity with its base. But basal nappes, which commonly have an allochthon of great thickness, as a rule, are sharply discordant with respect to the substrate; and cover nappes, usually of lesser thickness, have more chance of being "conformable" with the structures of the basement.

Among other things, Aubouin expresses the pessimistic thought that "it would be useless to try to give a more precise definition of nappes, since the number of their variants is countless" (Aubouin, 1967, P. 165). If what Aubouin had in mind was a structural classification of nappes, we have a more optimistics frame of mind and are prepared to attempt another step toward Improving the general classification of nappes. But the development of a perfect general classification, including genetic and geodynamic aspects, is still a matter for the future.

The geology of regions with extensively developed nappes has recently attracted increasing attention. As examples, one may cite the publications of S. V. Ruzhentsev (1968, 1977) on the tectonic layering of the lithosphere and the mechanism of development of stripped nappes; of I. I. Belostoskiy (1970, 1978), who considers mass overthrusts to result from the combined action of several interrelated mechanisms, which has a direct relation to the development of a general concept of nappe formation; of N. S. Kuteynikova and Ye. S. Kuteynikov (Kuteynikova and Kuteynikov, 1987), who have analyzed the very Important Images of mass overthrusts on space–satellite photos of the Alpine–Carpathian–Balkan region and western Kamchatka, which have the form of vertical structures; and many others.

We shall turn to another aspect of the geology of mass overthrusts and imbricate–overthrust structures–their morphology: that is, we shall consider them from the standpoint not of geodynamics but of structural geology.

We also take risk of proposing certain new terms, in full realization that the existing structural–tectonic terms already are certainly many hundreds in number and that new terms generally do not meet with approval, especially if they are complicated or sound unfamiliar. They are either repudiated or else simply forgotten. But the structural terminology as applied to these forms of structures is still undeveloped and incomplete, and an urgent need for it is felt, especially in geologic–survey production work.

Thus, efforts must be made to see that 1) the structural term be comprehensible and easy to remember, 2) that it be as simple as possible, 3) that it reflect the form of the geologic body, 4) that it have some continuity with previously existing terms, and 5) that it have no genetic, geodynamic or geomorphological content, but be purely structural–morphological.

We believe that any nappe structure can be named by using the following formula for the construction of the term: nappe+internal structure of allochthon+form of its base.

For nappe structures of limited size, made up of unit folds some tens or hundreds of meters to a few kilometers in extend, we propose the term "nappe–anticline" and "nappe-syncline" or "thrust-sheet anticline" and "thrust-sheet syncline". By nappe-anticline is meant a nappe that is completely or almost completely isolated from its roots, with an anticlinal structure of the stratified rocks of the allochthon. The corresponding definition applies to the nappe-syncline.

An excellent example can be seen in the sections presented by S. V. Ruzhentsev (1968) for the eastern part of the central Pamir Range. Figure 2 shows very clearly that the sandstones and shales of Middle to Late Ordovician age, buckled into a simple synclinal fold, have been overthrusts upon folds made up of Upper Triassic shales. In this case we have a nappe-syncline. It must be stipulated, however, that these structures may turn out actually to be the tectonic outliers of a mass thrust sheet of considerable size. But, of course, there can also be cases in which mass thrust sheets are made up of large single folds.

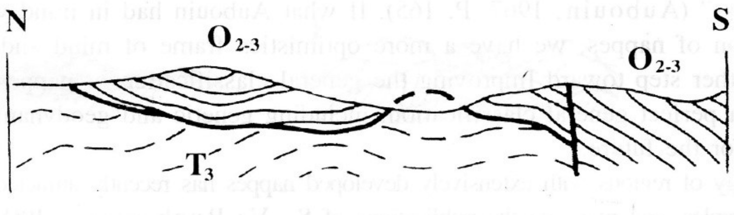

Fig. 2. Nappe-syncline; geologic section (7–8 km) along the left bank of the Kozynda River; eastern margin of the central Pamir region. Upper Ordovician clay shales and sandstones tectonically overlie Upper Triassic shales. (After S. V. Ruzhentsev, 1968.)

Сл. 2. Навлака-синклинала; геолошки профил (7-8 km) дуж леве обале реке Козинде; источни обод средњег Памира. Горњеордовицијски глинци и пешчари тектонски належу на горњетријаске глинце. (према С. В. Руженцеву, 1968.)

For structures of regional size extending over many tens or a few hundreds of kilometers, which have been stripped away and moved for considerable distances and have an anticlinal structure, we propose the term "nappe-anticlinorium", and for the analogous negative structure of the allochthon, "nappe-synclinorium". On small-scale geologic maps such large structures may often be mistaken for formations that have not been torn away their roots, which leads to fundamental errors. Some suggestions for improving the clarity and informativeness of geologic maps of regions with a nappe-folded-nappe structure will be made at the end of this article.

One must acknowledge the possible existence of "nappe-megaanticlinoria"-that is, structures many hundreds or even a few thousands of kilometers in extent and many tens or a few hundreds of kilometers in width; but whether such structures actually do exist is still a big question. At any rate, the raising of this question is fully justified (Dotduyev, 1986).

If the allochthon has a homocline structure, the term "nappe-homocline" may be proposed. An example can be seen in a geologic section presented in a monograph by G. D. Azhgirey (1977) and based on materials of B. Asklund from the Caledonides of Scandinavia (Fig.). In the region of Lake Strosjtin ("Great Lake") in central Sweden, the Archean metamorphic rocks are monotonically overlain, with a deep erosional hiatus, by thin (350 m) Cambrian and Ordovician deposits, which in turn are "conformably" overlain, along a tectonic contact, by the Vemdal quartzites of Vendlan age. In this case we have a typical conformable nappe. The conformabllity of nappes is an additional characteristic of theirs: for example, a "conformable nappe–syncline." It is clear that what is being represented is a synclinal fold of the allochthon inserted into a syncline of the autochthon. In the case of a lack of conformity of the structures we will have a "disconformable nappe–syncline" or any other kind of structure.

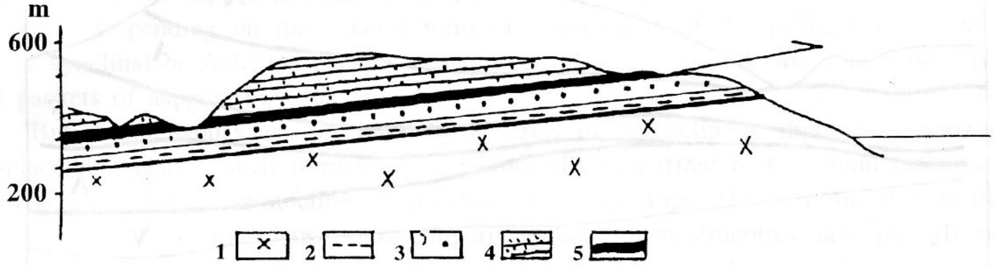

Fig. 3. Nappe–homocline: top of allochthon and lower sheet of the area of Lake Storsjon, Sweden; from G. D. Azhgirey, 1977, simplifed; 1–3): 1) Archean, 2) Cambrian, 3) Ordovician; 4) mass–thrust sheet of Vemdal quartzites (Vendian); 5) overthrust plane.

Сл. 3. Навлака-хомоклинала; највиши алохтон и доњи ниво области језера Сторсјон; из Г. Д. Ажгиреја, 1977, упрошћено; 1-3: 1) археј, 2) камбриј; 3) ордовицијум; 4) шаријаж вемдалских кварцита (Венд); 5) раван навлачења.

The terms "antiform" and "synform" are now commonly used. These structures are folds that close at the top or bottom, respectively (Mezhdunarodnyy, 1982). It should be noted in passing that the closing of folds is a concept that properly applies to a horizontal surface (a centriclinal closure or plunge), but here means the fold hinge. The terms under discussion here are to be used with out regard to the stratigraphic succession here are to be used with out regard to the stratigraphic succession of the beds. It should be stressed that no systematic classification of these structures has been developed, so that no systematic classification of these structures has been developed, so that they have become terms for free use. To all appearances, the description of synforms and antiforms should follow the rules applied to ordinary folds: "recumbent antiform," "fanshaped synform," etc., the preference in the use of these terms must be given to the internal structures of metamorphic or ophiolithic complexes. It is perhaps appropriate to do this also in regard to plunging folds and roullete–folds within the structure of the allochthon. It is obvious that if the allochthon is an intrusive mass stripped away from its roots, it the allochthon is an intrusive mass stripped away from its roots, it should be called a "nappe–lopolith" or "nappe–batholith" on the basis of the form of the mass.

Of great significance for nappe structures is the form of the displacement plane of the thrust sheet, which may be represented either by a shater zone or by gypsiferous or salt–bearing deposits, or again by serpentinite melange. It may be approximately smooth, horizontal or slightly dipping, convex upward ("anticlinal"), concave upward ("synclinal"), or most commonly complicated and uneven. The character of the displacement plane, if it can be reconstructed and substantiated, should enter into the specification of the particular form of the thrust sheet. The form of the displacement plan of the thrust sheet. The form of the displacement plan of the thrust sheet can be established in well exposed mountain regions with sharply manifested erosional relief.

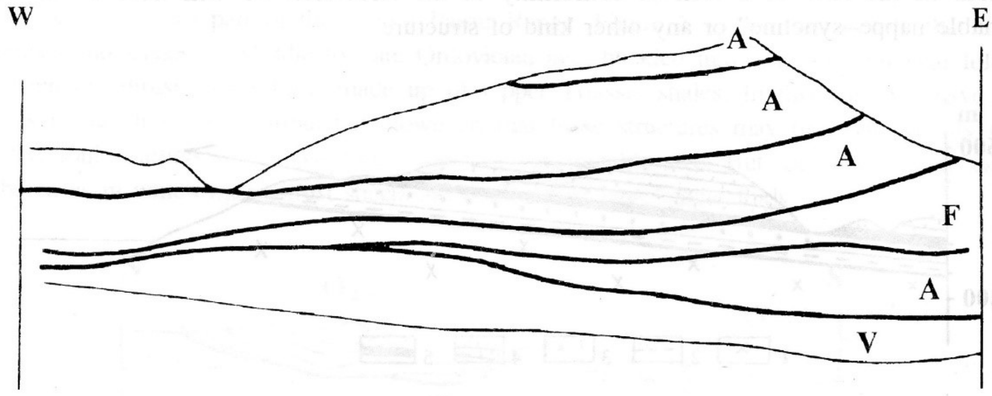

Fig. 4. Homocline of nappes grading into an accline, in the shore cliff at Cape Mjolner, Greenland (drawn from photograph); A) Ordovician conglomerates and limestones; V) Upper Cambrian siltstones. Height of exposure up to 1100 m; after S. Pedersen, 1986.

Сл. 4. Хомоклинала навлака које прелазе у антиклиналу, у обалској литици Кејп Мјолнера на Гренланду (цртеж према фотографији); A) ордовицијски конгломерати и кречњаци; Б) горњекамбријски алевролити. Висина откривености до 1100 m; према С. Педерсену, 1986.

An example of the full characterization of a folded–nappe structure with an internal anticlinorial structure of the allochthon and a concave–upward displacement plane is, shall we say, a "synclinal nappe–anticlinorium". But if the surface of the ruptural displacement plane is complex and very uneven, one can use, for example, the term "polyclinal nappe–anticlinorium."* In actual practice, however, the form of the displacement plane cannot be established in most instances, so that one is left only with the main part of the term without its additional characterization: for example, "nappe–synclinorium," etc.

A comparatively even displacement plane of a nappe, approaching some planar form, rarely occurs. In the case of a concave–upward base of the allochthon, the reason for this might be either the negative relief forms, if the nappe is post–erosional (subarelal or subaqueous), or else one must suppose that there has been a "plowing up" and squeezing of the autochthonous rocks by the weight of the rocks overthrust upon them. But if the displacement plane of the thrust sheet is convex upward, this can be explained by post erosional overthrusting upon a positive relief form and overthrust drag folding upon it. There may, of course, also be other causes, but the essence remains the same: the form of the bending of the displacement plane is the primary feature.

It is another matter when the displacement plane is deformed, and it is commonly strongly deformed by the post–thrusting forces of a later phase of folding; it may turn out to be torn by subsequent reverse faults or cuts, buckled into "folds," etc. These events can be reconstructed by field work and (or) detailed analysis of the fractures, signs of petrotectonic alterations in the rocks and other features.

We repeat, however, that what interests us is above all the final structure and its terminological identification.

In regions of complex folded–nappe structure, for example, in the French and Swiss Alps, the Dinarides, the Himalayas, the Koryak highland, or on the Japanese islands, multistage allochthons have been established; the nappe displacement planes fairly commonly have a similar and complex form, and they appear to be inset into one another as a result of post–nappe folding. It has been proposed that such archicomplex structural forms be called packets of nappes (Belostotskiy, 1970). This term must be acknowledged as appropriate. Depending on the general form of dislocations of the packets, they may be called synclinal or anticlinal packets of nappes, and in the general case folded or polyclinal packets of nappes (Fig. 1F).

But if the nappes are separated by a series of homoclinally dipping or horizontal displacement planes, such formations of tectonically reshuffled rocks should probably be called, respectively, a monocline or an acline of nappes (Figs. 1D. 1G), and it is to these that the name "tectonic plates" most properly applies. Such structures have recently been found in the south of northern Greenland, within the Lower Paleozoic terrigenous series. In such situations the internal structure of each tectonic plate and each "tectonic stage" in the dislocated packets of nappes may be complicated to any degree. But to name the entire tectonic structure of the packet as a whole, with allowance for the internal structure of each tectonic element, of the packet is more than likely impossible. In this case we are forced to share the well–known pessimism of J. Aubouin.

In many folded regions, the large anticlinal and synclinal zones are complicated by numerous overthrusts grading into nappes, steep listric reverse faults and normal faults that complicate the oblique and overturned folds. The overall structure turns out to be an imbricate reverse fault or imbricate–overthrust having a clearly manifested vergence, as a result of the horizontal movements of rock masses commonly in the direction of the adjacent marginal basins (in the eastern Carpathians) or rear inter–monatane basins (as on the south slope of the Greater Caucasus).

If the anticlinorium and synclinorium have an autochthonous position, a dense network of longitudinal listric fractures combined with transverse strike–slips substantially complicates the folded deformations and comes to prevail in the character of the entire structure as a whole–that is, we now have Imbricate–overthrust anticlinoria and synclinoria. This is what they are called, even though the structural terminology is thereby complicated by additional modifiers (thus–and–so and such–and–such). In order to introduce a single new term which is now lacking, we must perhaps turn to the Latin and Greek meanings of the term "scale". The Latin equivalent will be squama, and the Greek lepis (genitive lepidos). Thus, the choice of a single term must be made from the following set: "scale–anticlinorium", "squamanticlinorium" or "lepidanticlinorium". The first alternative is probably the least apt: one can only speak of a "scaled anticlinorium"*, but this is no longer a single term. It seems to us that the most appropriate may be the term "squamanticlinorium" (Fig. 1J). The structure of smaller order of magnitude may by analogy be called a "squamanticline". As an example, we can cite the structure of the Turner Valley oil field in the Canadian province of Alberta (Badgley, 1965) (Fig. 5).

After their development, such structures may subsequently be broken up into separate blocks, grabens and horsts. To retain the "memory" of the earner deformations, one can use an additional modifier of the name, as for example, "post-nappe horst". (Fig. 5).

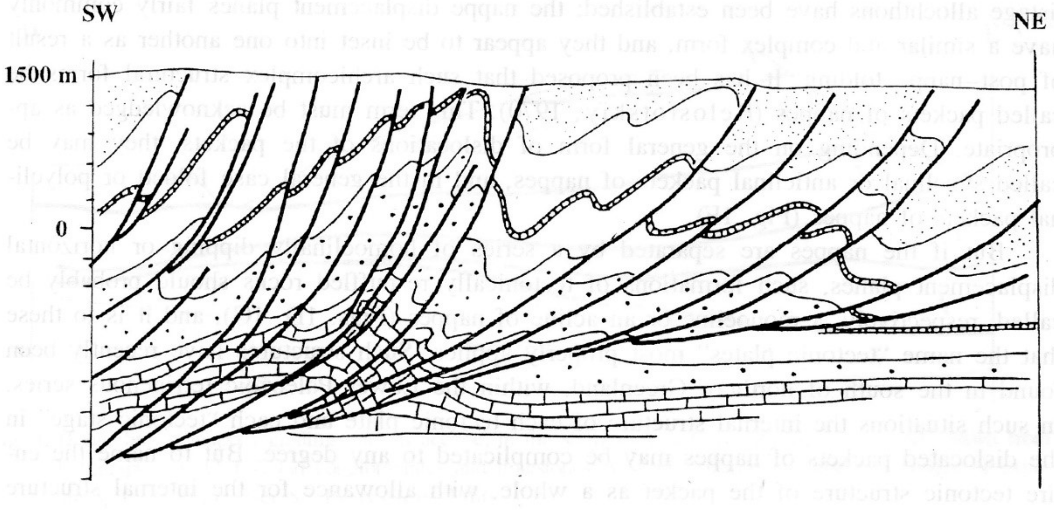

Fig. 5. Squamanticline within Turner Valley oil-field in the province of Alberta, Canada; various stippling indicate local stratigraphic units; after P. Bedgley, 1965, with simplifications.

Сл. 5. Скваматиклинала унутар нафтоносног поља у долини Тернер у канадској провинцији Алберта; различите шрафуре показују стратиграфске јединице; према П. Бедглеју, 1965, упрошћено.

Great caution must be observed in establishing the presence of nappe structures. For example, one may fairly often encounter synclines superimposed on older and more "rigid" rocks, whose basal layers have clearly been tectonized. The fact of the temptation to interpret the whole structure as a nappe structure-that is, as a nappe-syncline, in our sense, by analogy with another area. The tendency to discern nappes in any folded region can be attributed to the now common mobilist orientation of most geologists.

Let us take another example. In Central Kazakhstan, the Proterozoic metamorphic rocks in the Mt. Kotr area of the Dzhezkazgan district are overlain by superimposed troughs composed of Middle Devonian varicolored continental deposits, whose basal strata are sheared for an extent of several tens of meters. These have been described in detail by V. S. Mileyev in one of his field reports. One of the present writers has seen such phenomena in other areas of the Caledonides of Central Kazakhstan as well. The brecciation of the basal stratum, and also the bed-by-bed brecciations at higher stratigraphic levels, can be explained by the "slippage" of some beds relative to the others. Such tectonized basal contacts have been very aptly called "passive tectonic contacts" by V. S. Mileyev (oral communication). M. R. Gulamov has also recently called attention to such phenomena (Gulamov, 1985). Passive tectonic contacts merit indication on large-scale geologic maps by a special symbol.

Now for a last suggestion, concerning geologic mapping. On colored geologic and tectonic maps, the bodies of rocks (formations, suites, series, complexes, intrusive rocks and protrusions) occurring allochthonously are most appropriately identified by a red color, and in the case of a black and white map, by some distinctive feature such as oblique cross hatching. Such a suggestion has already been made (Krasil'nikova and Mazarovich, 1984) and submitted for consideration at the All–Union Geological institute. Important information on the time of completion or the duration of the mass overthrust rocks on maps can be given in the form of a "denominator" index or directly on the displacement plane. Both the informativeness and readability on the large–scale survey, medium–scale and detailed maps will thereby be sharply increased.

We have not undertaken the task of proposing an exhaustive terminology for folded–nappe and imbricate–thrust–folded regions, but have marely touched on some of the simplest and most general cases, and will receive with gratitude all critical remarks and additions that may be made on the subject under consideration. We are also sincerely grateful Ye. Ye. Milanovskiy and Yu. M. Pushcharovskiy for reading the manuscript of this article and commenting on it.

Translated by authors