

PETROFABRICS (GEFÜGEKUNDE DER GESTEINE) AND OROGENESIS.¹

BRUNO SANDER.²

In the space at my disposal I can make but a brief reference to the petrofabric literature of importance to orogenesis since (11).³ In addition I will touch on some of the very numerous relations between petrofabrics and orogenesis.

I use orogenesis in a wider sense than many tectonists. Likewise, petrofabrics⁴ is used in the broad sense of (11), and deformed rocks, crystalline grain fabrics (Korngefüge), etc., are only some of the chapters of petrofabrics. There ought not to be microtectonists and megatectonists working independently of each other, but rather one group of workers investigating the correlations between processes in large and in small units.

The importance of petrofabrics for orogenesis will not be over-emphasized here. As the literature up to now shows clearly, petrofabrics affords sometimes more, sometimes less information than is assumed. There are many problems even of petrotectonic character which can not be solved by petrofabric analysis alone. On the other hand, petrofabric analysis is indispensable for orogenic and many practical problems. The data afforded by new papers are of value even though the diagrams are not correlated with the problems of petrofabrics.

Summarizing the latest petrofabric analyses, one sees many and important new facts, new and independent possibilities for the characterization of geologic bodies, and new problems. The concepts of petrofabrics are growing and changing. Besides the students of the Innsbruck department many other workers from Germany, America, Finland, Italy, and Switzerland have taken part in this work. Investigators from all these countries have worked in the Innsbruck department in spite of the very limited apparatus available, and I for my part owe them many thanks for unpublished analyses.

The mere data of petrofabrics to-day comprise so many

¹ Previous study of petrofabric literature, particularly of E. B. Knopf's paper on Petrotectonics (this Journal, vol. XXV, June 1933), is assumed.

² In the translation and editing of this paper I am much indebted to H. W. Fairbairn and E. B. Knopf for their kind assistance.

³ The numbers in parentheses refer to the bibliography at the end of this paper.

⁴ Petrofabrics denotes the study of the internal space relations of a rock. (Editor.)

points of view and raise so many questions that it is possible to consider petrofabrics as an independent study and to pursue it as such. Petrofabric analysis is also important for purely petrographic investigations that seek only descriptive characteristics of rocks. For instance it is a totally different thing to talk about a granite whose fabric is clearly determined from the standpoint of rock classification and orogenesis than it is to speak of a granite whose fabric is unknown or only conjectured. Studies that are devoted purely to petrofabric problems (11, 13) would be of great value for the science of petrofabrics but are still seldom found in the literature.

Most papers deal with older geological problems. A great many of the papers consider orogenic problems and apply themselves particularly to the orogenic synthesis of the region under consideration. Geology needs petrofabric analysis not less than petrofabric analysis needs geology.

The summary of the literature shows clearly the success of the work and also what can be easily improved. In many studies the orientation of the diagrams in relation to geographical coördinates and to the fabric axes that are visible in the field is inadequate or not clearly presented. In some papers only the megascopic fabric (joints, schistosity, axes, etc.) is given, in others only the grain fabric. Both should be measured and presented together in their true orientation to each other. Some workers do not measure *all* the easily measurable minerals. Many others pay attention only to grain orientation and neglect other fabric data, especially the fine joints parallel to at least one of the *a*, *b*, *c* axes of the fabric. These joints can only be measured under the microscope and many of them are identical with megascopic joints. The relation of these microscopic joints to the grain fabric is more exactly determinable than the relation between megascopic joints and grain fabric. Valuable data are lost without a corresponding saving of time because too few partial diagrams are made. Much more attention should be paid than formerly to the distribution of the grains in a rock which form a given maximum in the diagram. This distribution is a deciding datum for many general problems, as, for example, the problem to what extent (in reference to what maxima) a mechanically induced orientation ("mechanical ruling") is determined by the mechanical behavior (translation planes, etc.) of the single grains or by the mechanical behavior of the whole fabric. Many of the problems referred to in (11) and (13) have not yet been dealt with in the current literature.

The formulation of the problems and the methods of investigation change from one case to another and can only be completely evaluated by using all the data at hand. Furthermore, petrofabric analysis can be applied to geologic problems only if one is quite familiar with the current state of the problems of petrofabrics.

Experience teaches that the progress of petrofabric analysis and its application to orogenesis must be the result of establishing types of a sufficient number of natural and artificial fabrics. It is advantageous to make a deductive summary of the data that have been obtained as long as such deductions and their application to geologic problems are not over-estimated. Walter Schmidt (13) has recently given such deductions for mechanical deformations in a manner stimulating for orogenic problems.

It is not possible to report here the whole content of such papers, although it might be possible to summarize them in a much shorter manner than the authors have done by the use of the fabric coördinates a, b, c and the correlated loci of the fabric planes designated by h, k, l as in crystallography. Only the results of importance for orogenesis will be emphasized here.

Crystallines of Southwestern Germany.—In the Böllsteiner Odenwald on the Rhine Doris Korn (5) made a petrofabric analysis as follows.—Megascopic fabric and grain fabric agree in their symmetry, the B-axes and the fabric symmetry (generally orthorhombic) are the same throughout the whole area, regardless of the different rock types and of the different tectonic units that were formerly assumed to be present. Some results of this work are:

1. Discarding of the older controversial orogenic hypotheses. These divided an area quite homogeneous in its fabric into genetically diverse units.
2. Obtaining of fabric data, which must form the foundation for every future orogenic discussion of the area.
3. Contribution to the descriptive characteristics of granitic rocks which in the Odenwald (Klemm, Bubnoff) and elsewhere were objects of futile genetic controversies as to whether they should be termed granite or gneiss.
4. In this area as in many others the megascopic fabric and the grain fabric (i.e. all the data of use for constructing the picture of movement or *Bewegungsbild*) show the same orientation in the granite and in the schist.

The work of Dr. Korn was followed by a series (8, 15, 6) of petrofabric analyses that not only show the inapplicability of the orogenic units formerly assumed but also afford important bases for new syntheses. Such bases are the symmetry of elastic and permanent deformation, the relation of elastic and permanent deformation to one another, the areas of homogeneous stress and strain, the relation between the movement-picture of the granitic bodies and of their envelopes, etc.

In the Bavarian Forest and Danube region petrofabric analysis has indirectly aided in solving orogenic problems (1, 2, 7) by its characterization of heterogeneous inclusions in granites and by supplying data on the older fabric inclosed by holoblasts. Maroscheck (7) showed the granite of Mauthausen to be a B-tectonite and explained its tectonics by petrofabric analysis. This method of analysis showed also the necessity of defining the joint systems by establishing their position relative to the *a, b, c* axes of the grain fabric. This necessity, always emphasized by petrofabric analysis, is often shown in the literature. For example, Sahlstein (10) recently established that the use of grain fabric is the only means of making a tectonic synthesis of the granulite area in Lapland. The misunderstanding that may arise by determining merely the position of megascopic planes without establishing the precise orientation of individual grains is very clear in the Drescher-Scholtz controversy (1).⁵

Nothhaft obtained results in the Bavarian Forest of general importance to petrofabric analysis by his studies of blastomylonites and he established essential tectonic features by the recognition and interpretation of B-axes.

Granulite analyses.—The work of Seng in Saxony (14) and Sahlstein in Finland (10) shows that of the types of granulite diagrams in (11) the most common are not those which exactly correspond to strongly deformed tectonites, such as shown for example by diagrams 38 and 26-28 in (11). On the contrary, the commonest granulite fabrics are quartz fabrics

⁵ Scholtz maintained that the dioritic rock of Fürstenstein in the Bavarian Forest is an intrusive rock produced by magmatic differentiation. Drescher contends that the so-called diorite is in reality a hybrid rock resulting from the assimilation of paragneisses by a granitic magma. Scholtz cites in support of the intrusive origin of the supposed diorite certain joints that he interprets as cross (tension) joints formed above the intrusive conduit. Drescher shows by petrofabric analyses that these joints are not perpendicular to the axes of the grain fabric and therefore cannot be interpreted as cross (tension) joints. (Editor.)

of visible orthorhombic symmetry (11, D40-43) and having types of quartz maxima that are well-known also for other quartz tectonites. The possible relation of these quartz maxima to several distinct systems of fabric planes was suggested in (11) and was demonstrated by Rürger (9) for a Saxon granulite that showed two mutually perpendicular *s*-planes. We will try at Innsbruck to settle this problem by exact plotting of the manner in which the grains, having a defined position in the diagram, are distributed in a picture of the thin section. The opinions of Rürger (9) and Seng (14) agree with the opinions expressed in (11), in that paracrystalline deformed quartz fabrics may acquire an imprint (Aufprägung) as the result of even a very slight differential movement, as for instance the final imprint of some deformation. This possibility should also be considered for the Finnish granulites. In these granulites asymmetrically superposed fabrics argue against a complete reorientation and *therefore* against much tectonic transport. In Finland the next task will be to investigate whether *b* (B) coincides with the wide regional arc of the granulites and whether the symmetry plane (*ac*) stands vertical and parallel to the radii of the arc. If this proves correct, the Finnish granulites would be a normal axial mountain arc with the most common plane of symmetry and stress. The stress might be orthorhombic with slight differential movement, with or without transport in the direction of the radii of the arc. This problem will be discussed later by Sahlstein.

It will be seen therefore that there are many problems in granulite areas, some of general importance for orogenesis, which are to be investigated and to be solved only by means of petrofabric analysis.

Walter Schmidt, who has contributed much to the analysis of oriented fabrics, has also played an essential part in the application of fabric analysis to orogenesis. In one of the most important chapters on fabric analysis in (13) mechanical analysis is dealt with and applied theoretically to a typical Alpine orogenesis (Deckenbau).

Many of the deductions of W. Schmidt, but not all of them, agree with the facts and opinions of (11). Some opinions at variance with mine, which are of importance for orogenesis and which I will discuss elsewhere at more length, are:

1. The deduction that, unless a fabric is of mechanical origin, there is little possibility of making a definitive statement concerning it.

2. The separation of dynamics and kinematics in fabric analysis.
3. The deduction concerning mechanically induced orientation in fabrics of quartz and mica and the associated schistosity. Although these are based on special cases, they are given as general deductions.
4. The determination of the degree of anisotropy of rocks.
5. The treatment of some chief problems of the orientation of tectonites that are also discussed in (11). These problems are, whether we may consider a fabric as produced by rotation of individual grains or by rotation of the whole fabric in geometric relation to the deforming forces, and which maxima in a diagram are to be related to different fabric planes and which to different mechanisms of grain deformation.

These last mentioned problems especially are important for tectonics, for on their interpretation depends whether one may deduce from a tectonite diagram that deformation has occurred on one or on two sets of shear planes. These two types of deformation are of different tectonic significance; e.g., from a deformation having one set of shear planes it can be inferred that tectonic flow has occurred along a movement horizon (*Bewegungshorizont*), whereas from a deformation with two sets of shear planes it can be inferred that deformation took place "between more rigid jaws" or the two sets of shear planes can be interpreted as the final imprint of a compressive force produced by load. In contrast to the first type of deformation the latter type is not necessarily associated with much transport.

PROBLEMS OF IMPORTANCE IN THE RELATION BETWEEN
PETROFABRICS AND OROGENESIS.

Petrofabric analysis is now being undertaken in America and I am convinced that American work will be of the greatest importance for its further development. Therefore I deem it better to call attention to the most recent development of some problems that are important for the relation of petrofabrics to orogenesis rather than to attempt any elementary introduction to petrofabrics (4).

Areas with steep and with slightly inclined or horizontal ("flach") B-axes.—In (11) I have distinguished the following two most important cases, with or without much transport.

The hand grips a rod "B" with greater pressure perpendicular to B, than parallel to B. This rod may be:

- 1, vertical (structure with steep axes) or
- 2, horizontal (structure with slightly inclined or horizontal axes),
e.g., axial mountain structures with movements parallel to B
and with or without transport perpendicular to B.

The B-axes may also have intermediate positions as, for instance, in some rocks in the Alps having triclinic fabric.

If we now give "B" all the characteristics of its megascopic fabric and grain fabric (11) and replace the hand by the area that surrounds the considered area containing B, we have one of the most important and most general distinctions possible to make in the deformed parts of the earth's crust, regardless of whether the deformation has been continuous or discontinuous.

The distinction between these two types of regions is decisively aided in its practical application by the modern knowledge of the relation between grain fabric and joint fabric and by the new criteria for the recognition and interpretation of B-axes, even where these are not recognizable in the field. The mere regional inventory of these B-axes would enrich the tectonic earth-picture and probably change it.

To-day it is possible to distinguish these two stress types by the fabric (joints or grain fabric or both) when the orientation of the fabric axes and of geographic axes have been exactly determined. This can be done even if other tectonic criteria can not be successfully used. It is often possible to work out the relation of these two stress-types to the crystallization produced by metamorphism, and by magmatic solidification, with a resultant gain in knowledge of the stress and strain that prevailed in definite environments of the earth's crust during rock formation of different types. Such stresses may result in tectonic transport or may produce tectonites *in situ*. Such tectonites are rocks showing evidence of movements that can be integrated to the general plan of movement, but which do not show much transport.

Investigation of the fabric often reveals "Stresstektonik" in the sense of (11). "Stresstektonik" includes the results of stresses comparable to the elastic stresses in the simple cases of physics. These elastic stresses occur sometimes at the beginning, sometimes at the end of greater permanent deformations, sometimes without any connection with permanent

deformation. These cases are distinguishable by modern petrofabric analysis as has been shown by examples. Such a study of the accessible earth's crust would serve to characterize its behavior better than would merely the solution of the tectonic problems in the narrower sense.

Ever since 1914 I have emphasized and illustrated the significance and abundance of structures with steep B-axes. Recently Schmidegg, of the Innsbruck Department of Mineralogy, has obtained the proof of such structure by field observation, by areal mapping, and by grain fabric analysis. This work demonstrates that the former interpretation of these areas as mere "Deckentektonik" does not explain the structure actually visible and shows that the divisions of the "Deckensystematik" are false. Schmidegg's results totally change the orogenic synthesis (12).

Thus, it is evident that it is of great importance to the solution of tectonic problems to search with the help of modern petrofabrics for areas with steep axes.

Types of folding and orogenesis.—One cannot draw the movement-picture of a folded region without considering in advance what types of folds it contains in reference to their differential movements (Teilbewegungen). Therefore it is necessary first to classify the folds by the criteria discussed in (11) and (13), which will be supplemented by other unpublished investigations. If one makes such a classification, one should not assume that shear-folding by slip along parallel planes is proved just because a tectonite-fabric of homogeneous folds made homogeneous by shear planes is present. It is quite possible to find a homogeneous imprint and preferred orientation (Regelung) imposed on folds of any origin. In such cases the folds are not formed by the shear planes of this imprinted movement nor must they necessarily have originated as shear-folds in a great tectonic transport (movement-horizon; "Decke"). It is also important in this connection that we investigated oriented quartz fabrics in tectonites that have not undergone much transport and that do show unrotated joints correlated with the orientation of the grain fabric produced by precrystalline deformation. Also of importance are orthorhombically symmetric quartz fabrics that have originated from the final imprint of the deforming force on rocks *in situ*. Such rocks, as for instance, some granulites and others, may have earlier undergone a tectonic transport.

Further, the preferred orientation of quartz in shear planes within single quartz crystals shows that quartz fabrics may have acquired this orientation by mechanical deformation (passive orientation) but without undergoing much transport.

This necessity for revising tectonic profiles was first and foremost emphasized by Walter Schmidt from some examples of Decken-structures in Switzerland. Several re-interpretations of details were made by Schmidt and he attempted to determine the broader features of the tectonic history of a typical Decken-structure. The fabric analyses have not yet been published.

One can show in a systematic way by fabric analysis and by more precise definitions that it is possible to replace the ambiguous dynamic hypotheses that have had a merely schematic representation in many tectonic profiles. This will often be of importance in orogenic syntheses.

Relation between preferred orientation and amount of differential movement.—A problem of great importance for petrofabric analysis itself as well as for orogenesis, and whose final solution needs much work, comprises the following two points:

1. The minimum amount of differential movement and deformation that can produce an oriented grain fabric. This amount is often, as in the case of quartz, very slight, particularly so where the deformation is paracrystalline.
2. The conclusion that can be drawn from an oriented fabric concerning the amount of the differential movements and therefore concerning the magnitude of tectonic transport. In general definitive conclusion is not yet possible.

A preferred orientation may be produced without tectonic flow during tangential transport. For example, strongly oriented B-tectonites can be formed "between moving jaws" without transport along a movement horizon. Often their deformation parallel to B may be even greater than the deformation perpendicular to B. There may be a lengthening (*Dehnung*) parallel to B or various types of shortening (*Stauchung*) parallel to B, including cross folding, due to inhomogenities. In addition we have studied in Innsbruck, limestones that do not show much transport, which have girdles, B-axes, and joints perpendicular to B (unpublished measurements by Ladurner on the Cretaceous limestone, Euganean Hills, Italy).

Often only the last chapter of the deformation can be inferred from the fabric. In other cases one can obtain by petrofabric analyses an insight into the earlier chapters also, including cases that show the imprint of more than one independent movement.

When the oldest fabric still perceptible in a rock has been determined, the history of the rock is deciphered as far as can be done by petrofabric analysis. If the geologist is interested in still earlier tectonic stages or in the magnitude of tectonic transport, there are other means of investigation. It is better to attempt no answer to such questions than to endanger the development of the fabric analysis.

To give to "load-metamorphosed" rocks an exact and practically determinable criterion one must apply a fabric-criterion. This criterion is the absence of any deformation fabric, even of the lowest degree determinable at present by fabric analysis. In such a case the rock has undergone loading without movement: It is purely "load-metamorphosed." Assuming constant volume, no fabric is known at present that can be ascribed to load without movement, i.e., without differential movement in the rock and hence without the development of tectonite-fabric. And if the term "load metamorphism" is applied to rocks having a low degree of deformation fabric, it is practically impossible to distinguish the metamorphism of these rocks from that of other tectonites.

The absence of deformation is not proved in all cases just because no preferred orientation is perceptible by optic or X-ray methods and because there are apparently undistorted features such as cross-bedding. This fact was discovered at Innsbruck by investigating the embedding limestone of distorted fossils and also by studying apparently undistorted cross-bedding.

In conclusion, it is possible at present to recognize tectonic movement on a large scale by comparison of several criteria of many well-characterized tectonites but not by consideration of oriented grain fabric alone.

Fusion tectonites (Schmelztektonite) and granites with oriented fabrics.—The fabric of solidified melts containing phenocrysts showed in many cases orientation according to grain shape (Regelung nach der Korngestalt), B-tectonites and S-tectonites oriented by grain shape. We have also described how the picture of the extrusive movement can be derived from the fabric, for example, in the quartz porphyry

in Saxony. M. Johs has recently dealt with similar problems (3).

In addition we meet again the old question, also of importance for orogenesis, of the relation in time between a parallel fabric in granitic rocks and the initial crystallization. Grain-fabric analysis leads to the following distinctions:

1. Granites that took on during their initial crystallization a fabric orientation similar to the fabric orientation of the inclosing rocks.
2. Granites that took on the same orientation as that of the inclosing rocks at a time later than the initial crystallization.
3. Granites that never took on the same orientation as the inclosing rocks or never took on any orientation in their fabric.

We know at present by grain-fabric analysis that typical granites whose texture has always been interpreted as the result of primary crystallization, such as the granite of Mauthausen in Austria studied by Maroscheck, may show the same grain-lattice orientation (*Regelung nach dem Kornfeinbau*) as rocks that were never molten. Therefore these granites have been subjected to conditions such that there has resulted an essentially or entirely similar portrayal of stresses and deformations as occurs in para-rocks.

Although we may not infer finally all the "portrayal" (*Abbildung*) and preferred orientation from the behavior of the single grain, nevertheless the preferred orientation of the grain fabric supplies the most intimate information we have concerning that behavior. The improved state of our knowledge at present is therefore as follows: There are granitic areas with constant symmetry of stresses. In these areas nearly the same conditions prevailed in granitic rocks and para-rocks. This is true both for the grain fabric which shows an older orientation inclosed by holoblasts, as well as for the grain fabric showing an orientation that was developed later. For these reasons we can speak either of "solidification" in the enveloping paraschists as well as in the granite, or else we should not use the word in either case. In respect to oriented fabric just as in mineral facies the difference between primary and secondary rocks vanishes at sufficient depth. Similar conditions are proved by like kind of orientation.

Likewise no boundary can be drawn by fabric analysis between plastic veinlike mylonites, blastomylonites, and fusion tectonites. These rocks cannot be distinguished by grain

fabric any more than they can be distinguished by intrusive or other criteria. Fabric analysis does, however, afford the information that genetic differences heretofore assumed do not exist; and the recognition of this very lack of genetic difference sheds light on conditions and processes.

The closer that the conditions prevailing in granitic fusion tectonites are approximated by other rocks, the more the grain-shape orientation of mica and the layering of the mica will be determined by slip along a single set of shear planes (einscharige Scherung) in the quartz-feldspar layers. This type of orientation may also occur in folds (13). This fact must be considered when interpreting folds in granitic rocks or in gneisses.

Depositional fabric (Anlagerungsgefüge) in Sediments.—As far as I know, no grain-fabric analysis of depositional fabrics has been published since (11). In connection with the general considerations of symmetry and grain-fabric analyses in (11) we have made in Innsbruck many optical and X-ray investigations of sediments. The new methods developed will be reported on elsewhere. Some results, in part of direct, in part of indirect importance for orogenic problems, are as follows:

- I. I found in many cases that it is possible to determine and to interpret the anisotropy in the deposition plane as defined in (11). These determinations are made with special apparatus that allows rotation of the rock around the axes perpendicular to the deposition-plane in relation to oblique light whose angle of incidence can be varied. Such determinations may be of importance in orogenic and economic problems, if one wishes to reconstruct a picture of the depositing medium (streaming, etc.).
- II. A second more extensive series of depositional fabric investigations dealt with limestones, dolomites, and limestone-dolomite rocks. They are chiefly Mesozoic Alpine sediments of either mechanical or chemical deposition, or superimposition of both, and with primary or secondary dolomite. Above all they show rhythmical systems of parallel planes which include layers whose thickness is of various orders of magnitude that are superimposed on one another in the same rock exposure. The thickness of the layers was determined by many hundreds of field and laboratory measurements. I consider the description and interpretation of these rhythmical systems to be just as important for orogenesis in the wider sense as tectonic studies.

Many of the deductions given in (11) are applicable to the description of these rock fabrics. Furthermore, by applying other methods more information in some respects could be obtained from the micro-fabric of these rocks than from the micro-fabric of tectonites, as, for example, information concerning internal erosion and deposition (*interne Abtragung und Anlagerung*) in the micro-fabric and the determination of top and bottom at the time of rock formation.

Grain-fabric analyses were made from homogeneous limestones and dolomites and also from typical homogeneous areas inclosed by inhomogeneous limestone and dolomite. The investigation of the inhomogeneous rocks gives better results the more carefully one selects the places in them to be studied. Such places should be: 1, defined as to genesis; 2, homogeneous in the particular areas exposed to the X-rays in each film or in the area comprised in thin section; and 3, defined in respect to their distribution and volume in the rock.

Study of the grain fabric of calcitic and dolomitic sediments disclosed:

1. Numerous fabrics of random arrangement in widespread rock types.
2. Several orientations determined by growth (*Wachstumsregelungen*) which are well defined and as a rule easily distinguishable from the characteristic orientation of tectonites. These growth-orientations may be present as partial fabrics (*Teilgefüge*), ranging from small up to very large parts of the rock.

These fabric analyses have contributed to the solution of the following problems:

1. The genetic interpretation of certain rhythmical beddings.
2. The more exact differentiation of calcareous sediments from one another.
3. The differentiation of undeformed calcareous sediments from calcareous tectonites by means of grain fabrics.
4. Early paradiagenetic movements in the environment of sedimentation.
5. Distinction between top and bottom at the time of rock formation by means of various and abundant "geopetal" fabrics.

Examples will be given elsewhere.

In order to avoid possible duplication I take this opportunity of enumerating the following unpublished work done in the

Innsbruck department, grain-fabric analyses of calcareous sediments by Ladurner and Felkel, gypsum by Fairbairn, corundum by Reithofer, and crystalline schists by Schmidegg.

BIBLIOGRAPHY (Partial)

1. Drescher, F. K. Zur Genese der Diorite von Fürstenstein. Neues Jahrb. f. Min., 60 B. B., Abt. A, pp. 445-530, 1930.
2. Hegemann, F. Ueber Feldspatflecken in Dioriten. Neues Jahrb. f. Min., Abt. A, Beil. Bd. 63, p. 173, 1931.
Tektonik und Entstehung dioritähnlicher Gesteine, ebendort Beil. Bd. 65, p. 233, 1932.
Mikroskopische, chemische und tektonische Untersuchungen zur Genesis der Diorite. Centralblatt f. Min., Abt. A, p. 369 u. 401, 1931.
3. Johs, Max. Der Granitporphyr von Thal Heiligenstein im Thüringerwald. Min. u. Pet. Mitt., Abt. B, pp. 283-319, 1933.
4. Knopf, E. B. Petrotectonics. This Journal, vol. 35, pp. 433-470, 1933.
5. Korn, Doris. Tektonische und gefügeanalytische Untersuchungen im Grundgebirge des Böllsteiner Odenwaldes. Neues Jahrb. f. Min., Beil. Bd. 62, Abt. B, p. 171, Stuttgart, 1928.
6. Korn, Lisbeth. Tektonische und gefügeanalytische Untersuchungen im kristallinen Vorspessart. Min. Petr. Mitt., vol. 43, p. 1, 1932.
7. Maroscheck, E. F. Beiträge zur Kenntnis des Granites von Mautausen. Min. Petr. Mitt., vol. 43, p. 375, 1933.
8. Portmann, W. Tektonische Untersuchungen im nördlichen Bergsträsser Odenwald. Heidelberg, 1928.
9. Rüger, L. Ueber einen Granulit mit "Sekundärschieferung" von Auerswalde in Sachsen. Sitzungsberichte der Heidelberger Akad. der Wissenschaften, math.-naturw. Klasse, 2. Abh., 1930.
10. Sahlstein, Th. G. Struktur und Bewegungen in der Granulitformation des Finnischen Lapplandes. Comptes Rendus de la société Géol. de Finlande, No. 6, p. 83, Helsingfors, 1933.
11. Sander, Bruno. Gefügekunde der Gesteine, 352 Seiten, 155 Abbildungen, 245 Diagramme. I. Springer, Wien, 1930.
12. Schmidegg, Oskar. Neue Ergebnisse in den südlichen Oetztaler Alpen. Verhand. Geol. Bundesanstalt Wien, 1933, Heft 6/7.
Geologische Spezialkarte der Republik Oesterreich, Blatt Sölden und St. Leonhard, 1932.
13. Schmidt, Walter. Tektonik und Verformungslehre. 208 Seiten, 49 Abbildungen. Borntraeger, Berlin, 1932.
14. Seng, Hermann. Die Gefügeeigenschaften von Granuliten. Min. u. Petr. Mitt., vol. 41, p. 453, 1931.
15. Wager, Rudolf. Tektonische Untersuchungen an einem Teil der Nord-schwarzwälder Granite. Badische Geol. Abhandlungen, Jahrg. I, Heft 2, und Jahrg. II, Heft 1, 1929/30.

ALTE UNIVERSITÄT,
INNSBRUCK, AUSTRIA.