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On some unusual twin-laws observed in the orthoclase crystals from Goodsprings, Nevada.

(With Plate I.)

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THE very abundant literature dealing with the twinning of felspar phenocrysts has put on record a surprisingly large number of twin-laws. Some of these have such complex indices that they have never been accepted; others are regarded as doubtful. Yet the authors of these have well-established reputations and the accuracy of their observations cannot be doubted.[1] The difficulty lies in the interpretation of the results. Beside numerous examples of well-defined laws, one comes across a high percentage of isolated cases, each appearing quite as plausible as these, yet difficult to assign to any definite law.

F. Klockmann[2] gave a number of suggestions for their explanation, based on the superposition of similar angles in different zones. This idea was expanded by G. Tschermak[3] and by H. Baumhauer.[4] These purely geometrical considerations gave rise to the notion of 'hetero-zwillinge' and 'zweiachsige Verwachsungen' which, instead of clearing up doubtful points, has only succeeded in introducing confusion. C. Viola[5] continues, however, in the same direction and these conclusions are accepted and utilized by petrographers, for whom the identification of twin-laws of the felspars serve in the determination of igneous rocks.

[1] For example: H. Laspeyres, Zeits. Kryst. Min., 1877, vol. 1, p. 346; W. Müller, ibid., 1890, vol. 17, p. 484; F. Gonnard, Bull. Soc. Min. France, 1883, vol. 6, p. 265; A. Vigier, ibid., 1909, vol. 32, p. 155.

[2] F. Klockmann, Zeits. Kryst. Min., 1882, vol. 6, p. 318.

[3] G. Tschermak, Min. Petr. Mitt., 1879, vol. 2, p. 499; 1887, vol. 8, p. 414.

[4] H. Baumhauer, Zeits. Kryst. Min., 1899, vol. 31, p. 252.

[5] C. Viola, Zeits. Kryst. Min., 1900, vol. 32, pp. 309–337; 1902, vol. 36, p. 234.

The lists of recognized 'felspar twins' given by them are based on the identification, by optical methods, of the mutual orientations of crystals found in juxtaposition in a thin section. The more cautious recognize, in many of these, the results of the *association* of several laws. E. S. Fedorov and W. Nikitin,[1] to mention one instance, still retain the double name 'Albite-Carlsbad' for one such association, while C. Viola gives it the name of the 'Scopi law'. V. Goldschmidt and R. Schröder[2] have proposed a number of such 'laws' based on purely geometrical juxtapositions. On the other hand, R. Sabot[3] classes one quite normal law, the Petschau law with twin-axis $[1\bar{1}0]$, among the associations of several laws.

The author was led to consult this literature when studying the twin-laws of the andesine phenocrysts from the Esterel 'blue porphyry'.[4] His object was to identify or obtain confirmation for some isolated cases or complex associations. He found that, before this could be done successfully, it would be necessary to determine, by more detailed examination of more convincing material, which laws were really well established. As a beginning in this direction, it seemed advisable to examine the cases of orthoclase twinning, for it is for this monoclinic felspar that the largest number of rather doubtful laws have been proposed. The results could, later, be extended to the plagioclases.

While in search of suitable material, the opportunity was given of studying a few orthoclase phenocrysts collected some time previously by Dr. W. F. Foshag, of Washington, at Crystal Pass, Goodsprings, Nevada. The author wishes to express here his best thanks to Dr. Foshag for this opportunity. Further material from this same locality was offered by Messrs. A. Montgomery and E. Over, two very keen American mineral collectors, and about a hundred specimens were received from them. This material seemed so ideal for the purpose that arrangements were made with Messrs. Montgomery and Over to collect a larger supply. In this they were very successful. They collected separately the whole of the phenocrysts from one large mass of rock, so that a quantitative estimate of frequencies could be made. Then they collected all the less common varieties from another large mass, to obtain plenty of useful material without being overloaded with excess

[1] E. S. Fedorov and W. Nikitin, quoted by R. Sabot, loc. cit., 1922, p. 110.

[2] V. Goldschmidt and R. Schröder, Beitr. Kryst. Min., 1923, vol. 2, p. 118. [Min. Abstr. 3-213.]

[3] R. Sabot, Bull. Soc. Franç. Min., 1922, vol. 45, p. 97. [M.A. 2-347.]

[4] J. Drugman, Bull. Soc. Franç. Min., 1925, vol. 48, p. 254. [M.A. 3-380.]

of the more ordinary cases. Broken material was discarded, but breakages seemed to be spread fairly uniformly over the different types, though, perhaps, Manebach twins, that separate easily along the composition-plane (001), may be underestimated as, also, some more fragile complex groups. The estimate is a rough one, but it gives a fair idea of the relative frequencies of well-developed twins. The following figures were obtained:—

Untwinned crystals	1830
Carlsbad twins	530
Baveno twins	60
Manebach twins...	60
Other twin-laws and complexes	195
Total	2675

A more detailed subdivision will be given farther on, in which will be included less obvious cases of twinning removed, after closer examination, from the 'untwinned' or 'Carlsbad' cases in the above estimate. Many cases will also be added where several laws are found side by side on the same specimen. The second lot of material yielded 135 picked specimens showing rare or complex associations. In spite of the high quality of the material and of its abundance, the object of this note was only partially attained, the same difficulties arising in the interpretation of isolated cases.

The rock is described as a much weathered granite-porphyry occurring as dike-like masses. Most of the crystals are pink or orange-red, some deep red, and others snow-white. These last seem to be completely altered, as is the rock in which they occur. Some crystals are fairly fresh, buff-coloured, and translucent. The phenocrysts are sharp and clean-cut; their habit simple and very constant. A large proportion only show (001), (010), and (110) in approximately equal development (pl. I, fig. 1). The ($\bar{2}01$) faces are very subordinate and often absent; (021), ($\bar{1}11$), and (130) are only occasionally met with. In normal-typed Manebach twins, however, faces ($\bar{2}01$) or ($\bar{1}11$) are well developed at the lower extremity.

Montgomery and Over noticed a number of much-rounded crystals whose edges were almost invariably bevelled by ($\bar{1}11$), (021), and (130), and supposed they had been derived from a special portion of rock. They, however, found a specimen on which the clean-cut and rounded types were embedded side by side. The rock has more the texture of a tuff, and these two varieties of crystals were probably enclosed in it when already formed.

From the first, wide divergencies were observed in the angles of some of the rarer cases that seemed, otherwise, to be of the same nature, and the publication of this note has in consequence been delayed. But similar divergencies were observed in cases that were undoubted Carlsbad or Baveno twins and even between the different elements of parallel growths. The specimens were, therefore, carefully selected and only those that seemed to be the most free from serious deviations were utilized. These deviations, which have been already recorded from other felspar localities, are probably due to pressure and strain in the rock.

The habit of the Goodsprings crystals is such a typical one and the variants from the normal type, of certain laws, so unusual that a photographic plate (pl. I) seemed the best means of rendering them. The line-drawings on the same scale on the transparent overlay explain these. The reproductions show the natural size of the crystals.

A. *Carlsbad law twins.*—Unlike Carlsbad twins from other localities, the habit of the constituent crystals is almost unchanged (pl. I, fig. 2*a*). There is little, if any, flattening on (010) and the elongation parallel to the *c*-axis is only observed in about half the number of Carlsbad twins. A second type is frequent (pl. I, fig. 2*b*) in which one crystal is predominant, the second emerging from a (001) face of the larger. This variety was frequently met with in the Esterel andesines. In these, the habit of the simple crystal remains generally quite unchanged. The more symmetric type of Carlsbad twin, when elongated in the direction of the *c*-axis, has a marked pseudo-hexagonal aspect.

B. *Manebach law twins.*—Two types are met with: a 'normal' type, elongated in the direction of the *a*-axis; and an undistorted type that can be termed the 'short type' of Manebach twin.

(1) *Normal type.*—The twin-plane is well-defined as composition-plane and the lower end is modified by the secondary forms generally observed in Manebach twins from other localities. The predominance of ($\bar{2}01$) gives rise to a 'blunt' lower termination (pl. I, fig. 3*a*), whereas the predominance of ($\bar{1}11$) leads to a 'bipointed' variety (pl. I, fig. 3*b*) in which the lower four-faced point is decidedly more acute than the upper one formed, invariably, of four (110) faces.

(2) *Short type Manebach twins.*—This type has already been observed in American orthoclases. The simple crystals retain their habit unaltered and there is no elongation parallel to the *a*-axis. Four (110) faces form the upper point and their parallels form a very pronounced re-entrant angle at the other end (pl. I, fig. 5). The two crystals interpenetrate and

often show complex interlocking at the upper points. The influence of a twin-plane seems, here, very subordinate and there is no visible composition-plane parallel to (001).

Between these two types, a number of interesting intermediate cases occur, most of them appearing to have originated in a normal-type twin. In these 'variants' the lower end always remains symmetric and may show either blunt or pointed terminations. At this end a composition-plane is quite obvious. But the upper end assumes more and more the characteristics of the short type. The upper ends interlock and one crystal is often prolonged much beyond the other (pl. I, fig. 4*a*) and often takes up the whole width, 'capping' the other (pl. I, fig. 4*b*). It would be interesting to investigate the reasons for this different behaviour at the two ends. The twin-plane seems to fill an essential role in the normal, long type, but not in the short type. A twin-axis is probably the dominant factor in the latter.[1] Whatever this factor is, it is a very local one, as is proved by one very interesting specimen. In this specimen, a long type and a short type Manebach twin are seen intercrossing in Carlsbad twinning (pl. I, fig. 6). Each type retains its characteristics in this complex, in spite of the intergrowth of the two.

C. *Baveno law twins.*—There is more uniformity in the development of the Baveno twins from Goodsprings, yet two types can be observed, showing similar differences. A normal type shows some elongation along the edge (001)/(010). It has a composition-plane roughly parallel to the twin-plane and no obvious re-entrant angles (pl. I, fig. 7).

The second type can, here too, be termed the 'short' type and is formed of unchanged simple crystals that interpenetrate with very obvious re-entrant angles (pl. I, figs. 8*a* and *b*). In some of these, the two crystals are sometimes joined end-on. There is no definite composition-plane.

D. *Twinning on face* (110) *and on face* (130).—A number of laws with twin-plane in the prism-zone have been described. But the only well-established ones are twinning on (110) and on (130). Examination of the Goodsprings material confirms this, though a few isolated specimens suggest the possible existence of other laws. These would, theoretically too, be much less probable.

Quite a number of twins on (110) have been identified in this material, three very symmetric ones being shown on the plate (pl. I, figs. 14*a*, *b*, *c*). Figs. 14*a* and *c* are shown in plan and 14*b* in elevation. Two or three

[1] Cf. G. Friedel, Étude sur les groupements cristallins. Bull. Soc. Indust. Minière, Saint-Étienne, 1904, ser. 4, vols. 3–4, p. 160.

twins on (130) have been identified, but this seems a less frequent aw than twinning on (110).

E. *Twinning on faces in zone* [010].—When this note was read before the Society in June 1936, two specimens (nos. 109 and 110) were exhibited that seemed to point to the existence of twinning on ($\bar{3}02$). A third, whose inclination of the *c*-axes differed rather widely from that of these two, was very like them in all other respects, so much so that, when hastily putting together a set of specimens to show at the meeting, it was included with these two. A more detailed examination of the material yielded a number of other specimens having in common the parallelism of the (010) faces, yet having different inclinations of the *c*-axes. It is in this zone that the twin-laws with the most improbable indices have been suggested in earlier literature. It seemed, therefore, doubly important that all doubtful cases in this zone should be examined with care.

Of the cases with parallel *b*-axes, a few were peculiar in that they could not be explained by a single operation, either rotation about an axis or reflection on a plane, whereas a 'tilt forward' of the *c*-axis of one crystal in the plane (010) would explain them. One was soon identified as an association of Carlsbad with Manebach twinning; it was, in fact, an example of the 'Carlsbad-Manebach' association, already observed in the andesines from the Esterel, in which the middle crystal, of the three associated together and acting as link to the two outer ones, was not visible. It was more than likely, therefore, that the other examples characterized by a 'tilt' forward of one crystal were also complex associations of these same two laws.

An examination of all the cases having (010) parallel showed that each of them could be explained by repeated association of these two laws, and that, at the same time, some of the most improbable of the laws with very complex indices could also be explained quite rationally by this same process. So as not to expand the explanation of each case unduly, the results arrived at are given in the form of a table (see opposite page).

The association of the Carlsbad and Manebach laws is frequent, so that association A is well established as a *limiting-case*, in which the middle crystal is masked by excessive development of the two outer ones. Each additional element makes the corresponding case less probable. But the frequency of the occurrence of the Manebach and Carlsbad laws is such that these more complex associations become quite possible. It is only a question of great abundance of material for such to come to light, as has been the case in this Goodsprings occurrence.

	Nature of assoc. C = Carlsbad M = Manebach.	Angle between *c*-axes.	Angle between (001) faces.	Observations.
A.	C–M 1–2–3	'tilt' of 52° 6′	127° 54′ (–52° 6′)	Nos. 352 and 353 from Goodsprings; Des Cloizeaux's Emfola law, with proposed twin-plane $(\bar{4}03)$.[1]
B.	C–M–C 1–2–3–4	52° 6′	75° 48′	Not observed at Goodsprings; probably Gonnard's supposed twin on (15.0.4).[2]
C.	M–C–M 1–2–3–4	104° 12′	52° 6′	Nos. 109 and 110 from Goodsprings; Vigier's supposed 'macle de St. Yvoine' twin-plane $(\bar{7}.0.11)$.[3]
D.	C–M–C–M 1–2–3–4–5	'tilt' of 104° 12′	104° 12′	No. 111 from Goodsprings.
E.	C–M–C–M–C 1–2–3–4–5–6	104° 12′	156° 18′ (–23° 42′)	Nos. 235, 352, 477 from Goodsprings.
F.	M–C–M–C–M 1–2–3–4–5–6	156° 18′	104° 12′	Nos. 351, 471, 542 from Goodsprings; Vigier's supposed 'macle no. 1', twin-plane $(\bar{15}.0.8)$.

The suggested laws with the very improbable indices $(\bar{4}03)$, $(\bar{7}.0.11)$, (15.0.4.), and $(\bar{15}.0.8)$ can be considered as disproved. The name 'Emfola law' has been adopted in a number of memoirs, and may be retained, as long as its true nature of association of the Carlsbad and Manebach laws be kept in mind.

F. *Twinning on a (hkl) face.*—A large number of very symmetric examples of twinning on some $(\bar{h}kl)$ faces were observed in the Goodsprings material. Both right- and left-handed varieties occur, that is, in which either a $(\bar{h}kl)$ or a $(\bar{h}\bar{k}l)$ face is twin-plane. The type of these is very uniform and the author suggests the term 'Goodsprings type' as a distinguishing term for it. A number of the better developed specimens gave measurements pointing to twinning on face $(\bar{1}12)$ or $(\bar{1}\bar{1}2)$ and the name Goodsprings law had at first been retained for it. But measurements of other specimens varied within such wide limits that the law cannot be definitively confirmed. It is therefore better to retain the name, temporarily, for the type only. (Pl. I, figs. 12*a* and *b*, *a′* and *b′*.)

[1] A. Des Cloizeaux, Manuel Min., 1862, pl. 25, fig. 149.

[2] F. Gonnard, Bull. Soc. Franç. Min., 1908, vol. 31, p. 286. While suggesting (15.0.4) as a possible twin-plane, he recognizes that the association can be explained by two operations.

[3] A. Vigier, Bull. Soc. Franç. Min., 1909, vol. 32, pp. 155–170.

A number of laws have been mentioned in felspar literature with (*hkl*) faces as twin-plane. Twinning on ($\bar{1}11$) is the only one, however, that seemed so far to be well established. One single specimen from Goodsprings confirms it. The theoretical angles for the law are very close to those for another law that will be described below. Only relative importance can, therefore, be attributed to this confirmation. One other isolated specimen, very symmetric in its development, points to the possibility of twinning on (111). Confirmatory evidence is, however, still lacking for it.

Some forty other specimens, mostly isolated cases, have not been identified and must, unless shown later to belong to some definite law, be temporarily classed as chance intergrowths. Two modes of grouping occur, however, that are each represented by a number of specimens, yet cannot with certainty be attributed to a definite law. They will, temporarily, be mentioned as possible laws X and Y.

G. *Twinning about axis* [$\bar{1}12$]; 'Nevada law'.—One isolated specimen was shown, when this paper was read, that pointed very decidedly to the existence of a law with twin-axis [$\bar{1}12$]. At the time, no other specimen had been identified, but this one was so convincing that there was little doubt of its true twin nature (pl. I, fig. 11). As this law is new, the name of 'Nevada law' is suggested for it. It has been conclusively confirmed by the discovery of twenty examples. The best-developed specimens show a marked pseudo-rhombohedral symmetry and a trigonal axis of twinning had first been looked for. But this supposition was not confirmed, measurements and the projections of these on a stereographic chart pointing conclusively to twinning about the axis [$\bar{1}12$], i.e. the edge between (110) and ($1\bar{1}\bar{1}$). One prism face (110) is parallel in the two crystals, as all other faces in the zone [$110/1\bar{1}\bar{1}$], namely ($0\bar{2}1$).

The example of twinning on ($\bar{1}11$), alluded to earlier, is very similar to the Nevada law twins; but, here, the ($\bar{1}11$) faces are strictly parallel, while there is a difference of several degrees in the Nevada law.

H. *Twinning about axis* [$1\bar{1}0$]; *Petschau law.*—This law was first observed by G. Tschermak at the Koppenstein, near Petschau, Bohemia.[1] It was confirmed, later, by V. Goldschmidt and F. E. Wright[2] and, more recently, by the author.[3] A number of examples were identified in the Goodsprings material, five at least being quite undoubtedly twins

[1] G. Tschermak, Min. Petr. Mitt., 1887, vol. 8, p. 414.

[2] V. Goldschmidt and F. E. Wright, Zeits. Kryst. Min., 1898, vol. 30, p. 300.

[3] J. Drugman, Bull. Soc. Franç. Min., 1928, vol. 51, p. 193. [M.A. 4–37.]

on the Petschau law. The angles of a number of other specimens differ, however, and the lack of parallelism of the (110) and (001) faces of a few is obvious. These seem to group themselves about two different means, but no definite laws are, so far, discernible. These are the two laws, or possible laws, temporarily termed the X and Y laws already alluded to.

It is the presence of such cases, that are not *quite* the same, that makes the study of orthoclase phenocrysts so difficult. The plausibility of some is such that one is often tempted to assign fixed characteristics to them, whereas they may be due to external causes in no way related to twinning.

If G. Friedel's suggestion of the existence of 'monoperiodic' and 'diperiodic' twins holds,[1] and his arguments for their existence are well considered, we may find that many of these doubtful cases will fall under one of these heads. A monoperiodic twin need only have the *direction* of one zone-axis in common, the other directing factors lacking. A well-developed face in such a zone would tend to fix the pair in some definite orientation, without actually being a twin-plane. A repetition of very similar cases would result, such as have been observed. It might be remarked that there would be little difference between these and 'heterozwillinge'. They are, however, based on one element of the lattice, common to both crystals, whereas in a 'heterozwilling' two unlike elements of the lattice are made to coincide. This is a purely geometrical operation in which the spacings in the lattice are not considered and, thus, with no sound scientific basis.

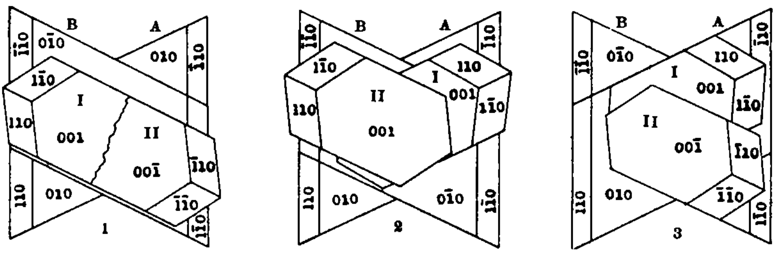
I. *Complex Associations.*—The conditions in which the phenocrysts of igneous rocks crystallize is very favourable to the formation of twins. There is, therefore, a tendency for these to be formed at all moments of growth of each crystal; hence the numerous cases in which several laws are observed on the same specimen. Their repetition gives rise to certain types that are so well defined, as we have already seen, that some have been treated as definite twins or 'heterozwillinge'. We will mention shortly the most frequent.

(*a*) The association of the Carlsbad and Manebach laws has already been described. It is the case observed by Des Cloizeaux from Cape Emfola, with the 'Carlsbad-Manebach association' as the limiting case. A further repetition of the same two laws gives complex groups, some of which had previously been described as twins with very high indices.

[1] G. Friedel, Bull. Soc. Franç. Min., 1933, vol. 56, p. 262. [M.A. 5-428.]

(*b*) Manebach twinning is often seen combined with Baveno twinning, though rare at Goodsprings.

(*c*) The association of the Carlsbad and Baveno laws is a very common one, both in orthoclase and some plagioclases (pl. I, fig. 9*a*). The limiting case, the 'Carlsbad-Baveno association', is even more frequent than that still showing the three crystals (pl. I, fig. 9*b*). Without defining it clearly, F. Gonnard shows it from Four-la-Brouque, while V. Goldschmidt and F. Paul[1] describe it as a 'heterozwilling', giving it the name of the 'Koppenstein law'.



FIGS. 1–3. Baveno twins on Carlsbad twins of orthoclase.

FIG. 1. It winned on (0$\bar{2}$1) of B; II on (0$\bar{2}\bar{1}$) of B.

FIG. 2. I twinned on (021) of A; II on (0$\bar{2}$1) of B. Plane of symmetry bisecting the obtuse angle between the (010) faces of I and II.

FIG. 3. I twinned on (021) of A; II on (0$\bar{2}\bar{1}$) of B. Plane of symmetry bisecting the acute angle between the (010) faces of I and II.

(*d*) A 'Carlsbad with Carlsbad-Baveno association' is also observed fairly frequently at Goodsprings (pl. I, fig. 10).

(*e*) 'Double Carlsbad-Baveno twinning', in which each of the Carlsbad pair has another crystal in Baveno twinning to it, also occurs, but is very rare. F. Gonnard mentions the possibility of a number of similar associations.

An example was found at Goodsprings in which Baveno twinning is repeated twice on the same crystal of a Carlsbad pair (text-fig. 1). One crystal is Baveno-twinned on the (0$\bar{2}$1) face, the other on the (0$\bar{2}\bar{1}$) face. These two crystals, lying on the same (010) face of the larger crystal simulate an 'end-on' Manebach twin. This gives a possible explanation to a case described by Müller where very improbable indices have been suggested for the twin-plane.[2] Very abundant material yielded four 'stellate twins' having (001) in one plane and the (010) faces at 127° 49′

[1] V. Goldschmidt and F. Paul, Zeits. Kryst. Min., 1909, vol. 46, p. 471.

[2] W. Müller, Zeits. Kryst. Min., 1890, vol. 17, p. 484.

to each other. The accuracy is not stated, but we may assume that, on such rough crystals, measurements were only approximate. This is close to the angle of the (001) faces of a Carlsbad twin. Baveno twinning repeated on the Carlsbad pair would give a 'double Carlsbad-Baveno' assemblage in all respects similar to Müller's specimens. Another peculiarity of Müller's specimens adds to the value of this new interpretation. Two of the four specimens have their ($\bar{2}01$) faces disposed symmetrically about the obtuse angle between the (010) faces, the other two symmetrically about the acute angle between the (010) faces. Müller had suggested a twin-plane ($\bar{8}63$). O. Mügge[1] suggested two different twin-laws for the two cases, namely, twinning about an axis [$\bar{4}30$] and twinning about an axis [$\bar{1}30$]. These interpretations are just as improbable as Müller's, whereas the two groups are explained quite simply as repeated Carlsbad-Baveno associations (text-figs. 2 and 3).

(*f*) There is one more mode of grouping, occurring generally in the form of a thin plate, with its (010) face resting on the (001) face of a larger crystal, which is frequent and also seems to occur in more symmetric pairs. It is very close to Baveno twinning, but, in this association, the edges (001)/(010) are not parallel, and the edge (110)/(010) of the small plate is parallel, or approximately parallel, to edge (110)/(001) of the larger crystal. A Carlsbad-Baveno equivalent to this association is also frequent, also in the form of a small plate on a larger crystal. These are temporarily termed pseudo-Baveno and pseudo-Carlsbad-Baveno associations. These are two cases that might be given as confirmation of the existence of 'heterozwillinge', for no rational explanation of them has yet been found.

The following table gives the number of specimens of the less common types, the 'quantitative material' being that collected by Messrs. Montgomery and Over from a single large mass of rock (p. 2).

Relative frequencies of less common laws and groups.

	Quantitative material.	Other material.
Manebach long type	23	13
,, 'capped'	18	9
,, 'short type'	25	7
Baveno long	16	14
,, short	56	7
Carlsbad with Manebach	16	12
Carlsbad with Manebach, repeated	1	—
'Carlsbad-Manebach'	2	—

[1] O. Mügge, Neues Jahrb. Min., 1890, vol. ii, p. 89.

Relative frequencies of less common laws and groups (*cont.*)

	Quantitative material.	Other material.
Complexes of Carlsbad and Manebach:		
c-axes near 156°	2	1
c-axes near 104°	1	2
c-axes tilted near 104°	—	1
c-axes near 76°	—	2
c-axes near 52°	—	2
c-axes tilted near 52°	—	2
Carlsbad with Baveno	18	10
,, ,, repeated	—	1
'Carlsbad-Baveno association'	25	13
Carlsbad with Carlsbad-Baveno	17	6
Manebach with Baveno	2	3
Carlsbad, Manebach, and Baveno	2	3
Twins on (110)	28	3
Twins on (130)	6	—
Undetermined cases with parallel *c*-axes	3	4
Goodsprings type twins	40	12
Nevada law	17	4
Petschau law	12	7
Twins on X and Y laws	10	9
Miscellaneous, undetermined cases	30	21

Conclusions.

Theoretical conclusions have been, as far as possible, excluded from this note. We will therefore consider only the practical results obtained. The difficult nature of the material, even that from this very interesting occurrence, still leaves doubtful and unexplained cases. A few new facts have, however, been obtained and some old doubts cleared up.

Besides the three common twin-laws of orthoclase, the Carlsbad, Baveno, and Manebach laws, the following less frequent ones have been observed:—

Twinning on (110) and on (130); no special names.
,, about axis [$1\bar{1}0$]; the Petschau law.
,, on ($\bar{1}11$); only one specimen.

The existence of the following laws has been shown:—

Twinning about axis [$\bar{1}12$]; the name 'Nevada law' is proposed.
,, on (111); only one specimen.
,, on a (*hkl*) face, measurements of a number of specimens near the theoretical angles for twinning on ($\bar{1}12$); others vary rather widely from the theoretical angles, and the law remains still doubtful. The type is, however, so uniform and typical that we may give it the

name 'Goodsprings type', since a definite name facilitates the discussion of a type or law. The author, however, suggests that, in theoretical discussion of frequent associations, the combined names of the laws be employed, their designation as a definite 'law' being misleading.

The possible existence of two other laws or modes of grouping are suggested by this material, with (*hkl*) twin-planes, temporarily termed the X and Y cases; also two modes of association near the Carlsbad and Carlsbad-Baveno positions that are given temporary names, the 'pseudo-Baveno' and 'pseudo-Carlsbad-Baveno' cases.

An important result, in the author's view, is the interpretation of a number of doubtful cases in the (100)/(001) zone as associations of the Carlsbad and Manebach laws. This interpretation affords an explanation of the following very doubtful 'laws':—

The 'Emfola' law (twinning on ($\bar{4}03$)), twinning on ($\bar{7}.0.11$), (15.0.4), and ($\overline{15}.0.8$); probably also twinning on (1.10.0) of Haushofer.

The interpretation of Müller's two cases as Carlsbad-Baveno cases renders unnecessary the twin-laws on ($\bar{8}63$), and on the axes [$\bar{4}30$] and [$\bar{1}30$].

The wide variation in the angles of cases with (*hkl*) twin-planes also points to the improbability of such laws as twinning on (661) and ($\bar{2}.5.15$) brought forward by K. Haushofer,[1] though measurements on adularia may give better readings than those on orthoclase.

Laws for which the Goodsprings material has brought no new data are twinning on ($\bar{2}01$) and on ($\bar{1}02$). Material from other localities is in support of twinning on ($\bar{2}01$); the other law is possible, but so near to Carlsbad twinning that it seems improbable.

[1] C. Hintze, Handbuch Min., 1897, vol. 2, p. 1342.

EXPLANATION OF PLATE I.

Crystals of orthoclase from Goodsprings, Nevada. Natural size.

FIG. 1. Untwinned crystal of normal Goodsprings habit.

FIG. 2. Carlsbad twins: (*a*) normal type; (*b*) unsymmetric type.

FIG. 3. Long type Manebach twins: (*a*) with blunt lower end; (*b*) with acute lower end.

FIG. 4. Abnormal development of Manebach twin: (*a*) one crystal longer; (*b*) 'capped' variety.

FIG. 5. Short type Manebach twin.

FIG. 6. Long and short types of Manebach twins associated in Carlsbad twinning.

FIG. 7. Normal type Baveno twin.

FIG. 8. (*a*) and (*b*) short type Baveno twins.

FIG. 9. (*a*) Carlsbad with Baveno; (*b*) 'Carlsbad-Baveno association'.

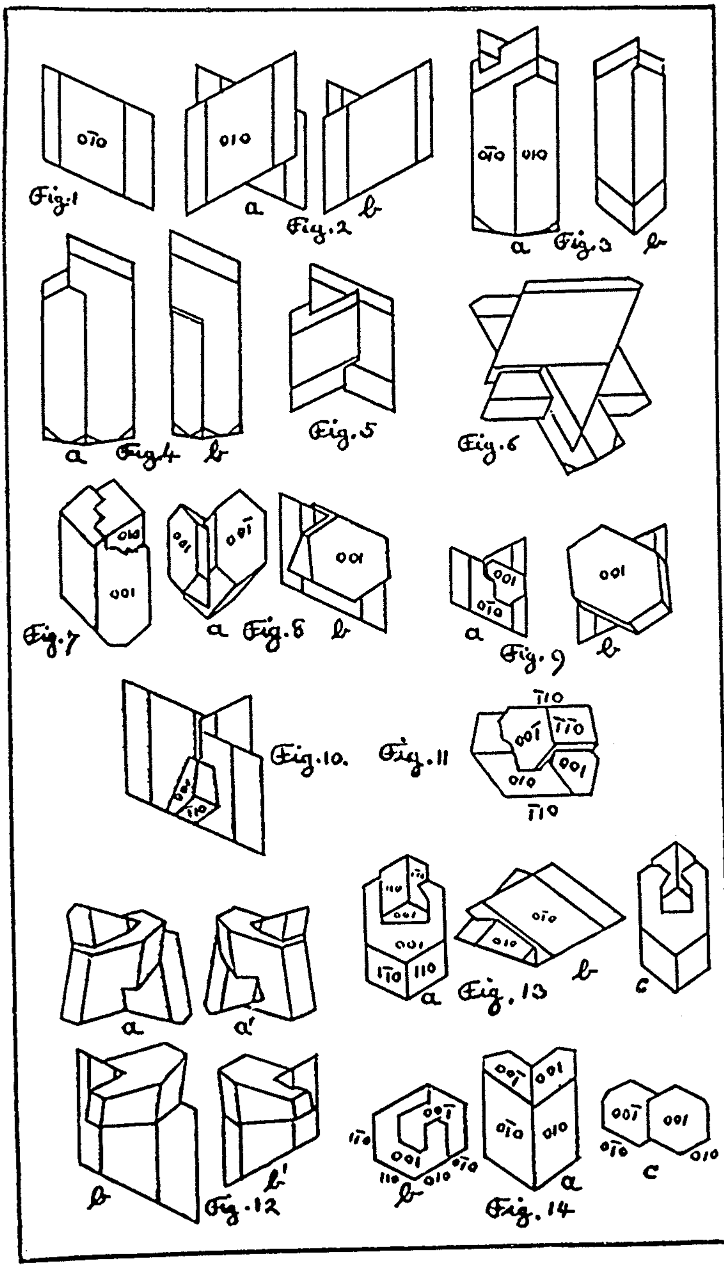
FIG. 10. Carlsbad with Carlsbad-Baveno.

FIG. 11. 'Nevada law' twin; twin-axis the edge (110)/($1\bar{1}1$). (The twin-axis is in the plane of the drawing and horizontal.)

FIG. 12. (*a*) and (*b*), (*a′*) and (*b′*). Goodsprings type, right and left.

FIG. 13. (*a*) and (*b*) 'Manebach-Carlsbad-Manebach association'. (*c*) 'Carlsbad-Manebach-Carlsbad-Manebach-Carlsbad association'.

FIG. 14. Twins on (110); (*a*) prism-zone vertical, in plane of drawing; (*b*) and (*c*) prism-zone normal to plane of drawing.



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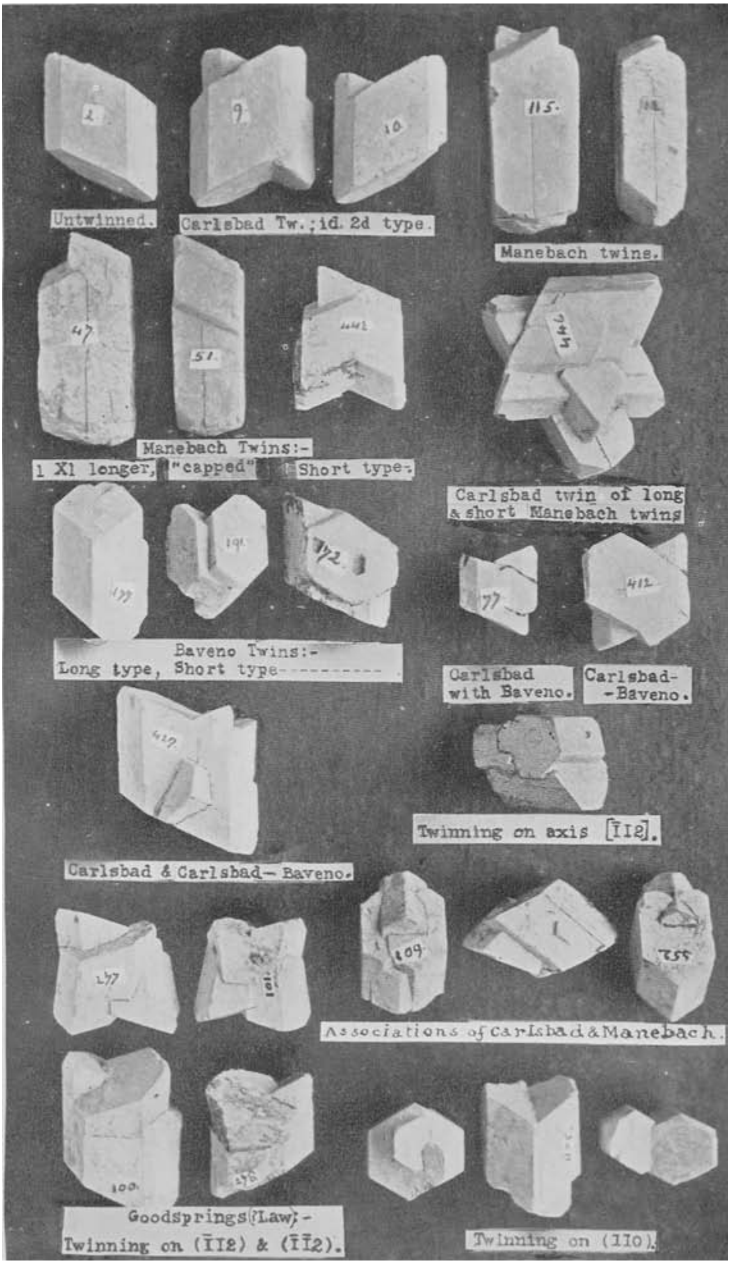

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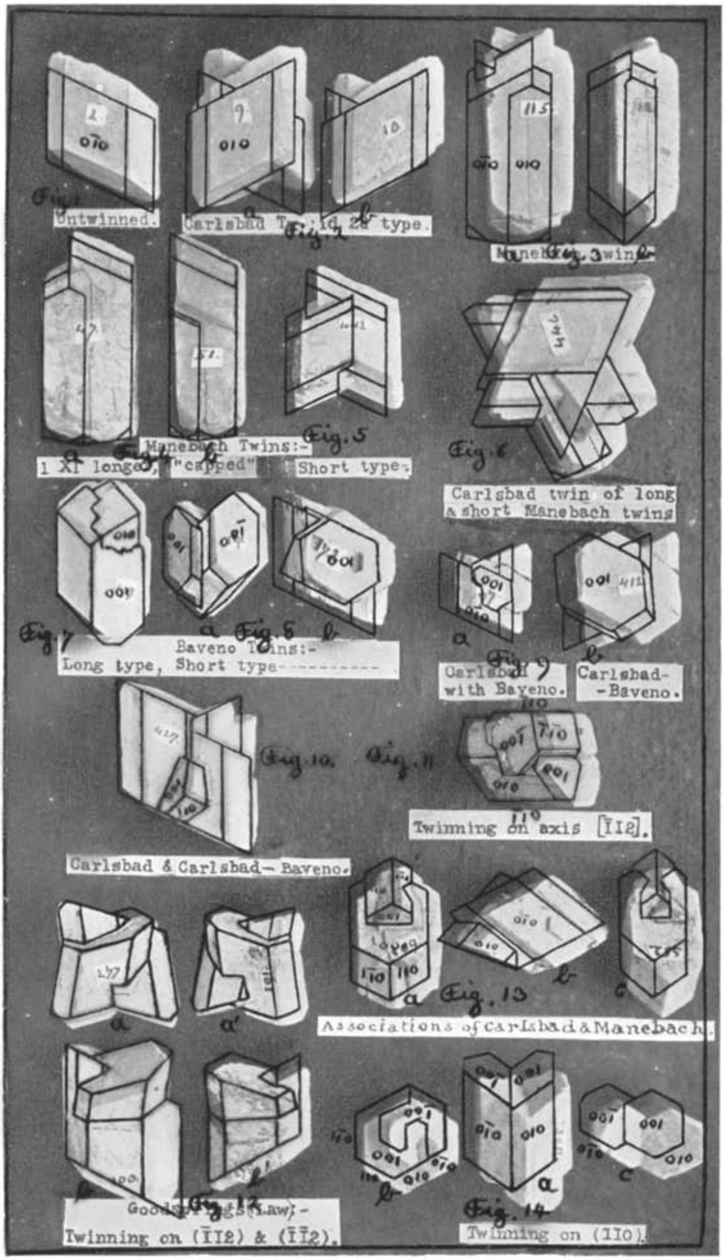

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