

PART III.

THE DURON AND POZZALE AREA.

The N.N.E.-S.S.W. Flexures and Faults—The Pozzale Section—Basal and Overthrust Masses—The Werfen Conglomerates in the Basal Mass—Packing in the Thrust-Mass—Overcasting of Earlier Plications towards South-West—Relation of the Pozzale Slopes and Rodella Berg—The Upper Fassa Cross-Arch—The Outcrop of the Main Thrust-Plane at Mt. Donna and Bufaure—Differential Horizontal Movements along the N.N.E.-S.S.W. Faults—Old Fissure Facies and Later Intercalations.

(Plates V., IX., X., XIb., XIc., and Plate XIII.)

The N.N.E.-S.S.W. Flexures and Faults.

The southern slopes of the Langkofl and Plattkofl Massives descend to the Duron Valley, which runs east and west and joins the Fassa Valley at the village of Campitello (height 1440 mètr. contour). The two chief streams descending southward to Duron Valley from the Langkofl and Plattkofl Mountain are the Pozzale and Chiarvenna streams, and the section afforded by the Pozzale ravine is one of the most instructive in the district.

Ascending Duron Valley from Campitello, one may observe that the Lower and Middle Triassic strata have been thrown into a series of broad arches with axes N.N.E.-S.S.W., or rather more towards north and south; and that the steep flexures between adjacent arches are locally developed as faults. These arches and faults affect the whole series of thrust-slices which build up the hill-slopes (Plate V.).

The first broad arch extends westward from Campitello for some distance up the valley, and the Mendola Dolomite which dips down the Mount Donna slope towards Campitello is part of the east wing of this arch. The Werfen strata immediately below the Mendola Dolomite are grey marls and marly limestones full of *Myophoria ovata*, and interbedded red marls (str. N. 75° E., dip 15° S.). A short distance from Campitello on the south side a fault-plane inclined towards the east is present in the Werfen strata, and it may be observed that the horizons of Werfen strata and Mendola Dolomite nearer Campitello are part of a thrust-slice resting upon the strata in the next higher part of the valley. The Werfen strata of the underthrust slice on the west contain rich banks of *Pleuromya Fassaensis* and various species of *Pseudomonotis*.

Immediately before the Pozzale stream is reached, a steep westward flexure of the strata on both sides of the Duron Valley

marks the position of the N.N.E.-S.S.W. fault between Rodella Berg and the Pozzale slope. The general E.N.E.-W.S.W. strike and south dip of the strata is locally altered near the flexure. I called this the "Pozzale fault" in my earlier descriptions of Fassa and Rodella.

Downthrow has been on the west, *i.e.* the side of Pozzale and the Langkofl Mountain, but at the valley level the strata on the west are as a matter of fact higher than the strata on the east. This is, however, due to the overcasting, packing, and shear-slicing of east-west folds in the Pozzale and Rodella area, in such a way that the originally higher and narrower portions of the overcast arches have been preserved in the downthrown Pozzale segment, and have at the N.N.E.-S.S.W. fault been brought laterally opposite axial and thicker portions in the Rodella segment. It does not appear to have been only a vertical displacement, but the two sides seem to have likewise suffered differential horizontal movement, the east side being driven relatively southward. This is simply a type of the horizontal displacements that have taken place at many faults, and which most assuredly demonstrate a high degree of torsion. Horizontal slickensides may frequently be seen at the surfaces of the rocks next the N.N.E.-S.S.W. faults.

Another N.N.E.-S.S.W. arch rises on the west, and this second arch descends steeply in the neighbourhood of the Chiarvenna stream and brings the Wengen lavas on both sides of the Duron Valley to the valley level at about the 1760 mètr. contour. The flexure is so steep that it is practically a flexure-fault with downthrow on the west side.

The Pozzale Section—Basal and Overthrust Masses (see Plate V.).

The Pozzale stream has cut through this second N.N.E.-S.S.W. arch at the parts where the arch is dipping eastward to the Pozzale N.N.E.-S.S.W. fault. Entering the Pozzale stream-cutting, the Werfen and Mendola strata are seen. They have a steep southward dip, but are also bent eastward; the eastward flexure is best seen on the left bank (Fig. 23A).

On the right bank the arching of the strata is displayed and the Upper Werfen (*Myophoria*) horizons are closely puckered above a shear-plane whose continuation may be followed westward for some distance until it passes into a precipitous crag, where it is concealed by thin vegetation (Fig. 23B). Its effect is to cut out more and more of the Upper Werfen horizons towards the west. The strata at the steep flexure shown in the sketch strike N. 55° E. and dip from 50° to 70° S.E. The surfaces of

the bedding-planes are slickensided, and the mass is cleaved in N.N.W.-S.S.E. direction. As this group of Werfen and Muschel-

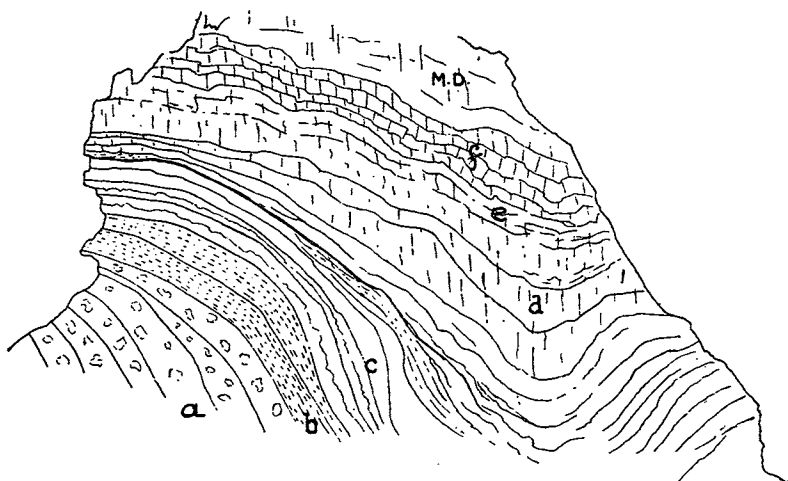


FIG. 23A.—Eastward Flexure of Upper Werfen and Mendola Dolomite on left bank of Pozzale stream. *a*=Red and Grey Conglomerates. *b*=Red, Grey, and Greenish Marls. *c*=Thick-bedded Oolites and Limestones. *d*=Sandy Limestones and Echinoderm Limestone interbedded with plant-bearing strata. *e*=Plant-bearing marly Limestones and Shales. *f*=Creamy oolitic Limestone and Myophoria Beds.

W.

E.

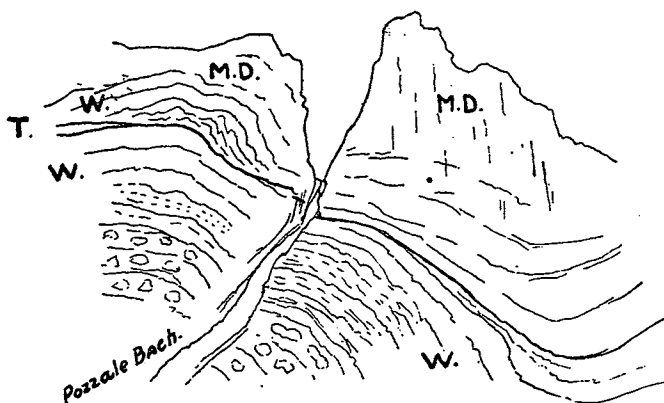


FIG. 23B.—T.=Bent Thrust-plane passing through Werfen Strata in the Pozzale Ravine. W.=Upper Werfen Strata. M.D.=Mendola Dolomitic Limestone.

kalk strata belongs to the basal mass above which the Rodella and Pozzale thrust-slices have been driven, I shall describe

the strata in more detail. The chief feature is the very gradual transition from Werfen to Muschelkalk horizons, and the more calcareous nature of the "Mendola" horizon.

The series exposed here below the Mendola Limestone comprises an upper group of bright yellow and creamy-tinted beds of sandy dolomite and oolitic limestone interlayered with marls, and a lower group of dark grey bituminous limestone, sandy plant shales, and crinoid limestones, resting upon the Upper Werfen reddish marls and pebble beds :—

Mendola horizon of dolomitic limestone.

- $\frac{1}{2}$ mètr. Lumpy limestone with wavy bedding surfaces (of Wellenkalk type).
- 4-5 mètr. Creamy oolitic limestone passing upward into "Myophoria" beds of limestone, dark-grey flaggy limestone, and yellow-weathering stratified dolomite.
- 8-10 mètr. Plant-bearing shales and marly limestones with occasional Lamellibranch fossils, much compressed; interbedded with thicker layers of yellow-weathering limestone (compare series below Langkofl, p. 34).
- 3 mètr. Dark, blue-grey bituminous limestone—a harder and heavier rock with Echinoderm remains.
- $3\frac{1}{2}$ mètr. Violet-grey limestone occasionally red-streaked and interbedded with soft marls and shaly limestone—plant stems abundant and muscovite flecks on the bedding surfaces (*Voltzia*, sp.?).
- 1 mètr. Rich "Myophoria" bed of limestone, but fossils crushed.
- 6 cm. Thin reddish marls.
- $\frac{1}{2}$ mètr. Dark, marly limestone, rich in plant remains—some of the stems are inch-wide, but most of them are finer and thinner.
- 4-6 mètr. Thick beds of oolite and oolitic limestone, creamy and yellowish; interbedded with grey shales, marls, and shaly limestone full of muscovite specks and containing plant remains.
- 4 mètr. Red, grey, and greenish marls and shales containing *Naticella costata*.
- 6 mètr. Conglomerates and marls.

The Werfen Conglomerates in the Basal Mass.

The series detailed above corresponds to the "Passage-beds" and Upper Werfen strata which I described fully in my paper

on "Monzoni and Fassa" and defined as a palæontological zone corresponding in position with the horizon of the "Myophoria Beds" or "Reichenhall Limestone in N. Tyrol and Bavaria."¹ It is very much thicker than the same horizons in the thrust-mass and is characterised by the plentiful occurrence of plant remains and the coarse conglomerate below the poikilitic marls.

Dr Philipp described a similar succession of oolites and marls in Val Averso in the Predazzo district, and pointed out that to the north of Val Averso in the Rosengarten, the upper group of oolite, shales, and dolomite above the bed of Myophoria Limestone was replaced by a reddish conglomerate,² which he regarded as a sedimentary facies. At Pozzale, the conglomerates are only present below the rich Myophoria beds of limestone, and distinctly underlie the series of red marls, plant shales, and oolites.

In the Schlern and Seiser Alpe area, above Bad Ratzes, I calculated that the coarse conglomerate was *ca.* 4 mètr. thick, and was succeeded by about 5 mètr. of red marls passing upwards into interbedded marls and limestone.

In the Vajolett Valley, to the west of Pozza in Fassa Valley, the marls and limestone below the Mendola horizons have well developed concretionary structure, which quite resembles the block-structure in the lavas, and seems to me a pressure-effect. The Upper Werfen series is thinner in the Vajolett Thal, the plant-bearing marly limestones and crinoid limestones being the horizons most reduced, while the sandy oolites predominate.

On the south of Bufaure and elsewhere, I have observed that the limestones immediately below the Mendola horizon, as well as various beds in the Upper Werfen series, tend to assume a conglomeratic or concretionary appearance where below a thrust-slice they have been closely kneaded into the marly strata associated with them. This is in my opinion a local appearance, developed at different horizons according as they are next a thrust-plane, or subjected to strong local pressure.

In the Pozzale ravine, the cementing material in the coarse Werfen conglomerates is the same reddish and variegated marl as in the strata immediately above. The included pebbles are of all sizes, mostly about the size of an egg, but some as large as a man's head. About 25 per cent. of the pebbles are of a dolomite rock which weathers yellow, and is pale yellow or pinkish in fresh fracture. Others of frequent occurrence

¹ Ogilvie Gordon, *Trans. Edin. Geol. Soc.*, 1902-3, Special Part, pp. 19, 113, 114, Plate VII.; the series is described by Mojsisovics in "Dolomit-Riffe" as Lower Muschelkalk (*loc. cit.*, pp. 46, 47).

² Dr Philipp, "Paläont.-Geol. Untersuchungen aus dem Gebiet von Predazzo" (*Zeitsch. d. D. geol. Ges.*, Bd. lvi., Jahrg. 1904).

are of reddish limestone and oolite, containing indefinite species of *Natica* and some Bivalves. Pebbles of banded grey and reddish limestone without fossils are also common, and more rarely pebbles of a grey limestone occur. Many of the pebbles show small indentations, and the bedding-planes have frequently fluted or polished surfaces.

Packing in the Thrust-Masses.

It is necessary to go a little west from the stream in order to ascend the Mendola Dolomite, but one should then return to the stream and follow it upward. The dolomite is succeeded by a small thickness of Upper Muschelkalk, and then by overthrust Werfen strata, showing pressure effects, and thrown into small plications and occasionally fractured. The strata resting upon the Upper Muschelkalk are the highly fossiliferous Werfen horizons with *Pseudomonotis Clarai* (str. N. 20° E., dip 25° S.E. bending to N.W.). These are succeeded by red marls and marly limestones and shales which keep repeating themselves in the stream-cutting owing to the plications.

At ca. 1800 mètr. contour where a tributary from the west joins the Pozzale stream, the Upper Werfen horizons of oolitic and thin-bedded limestones are present, and are tilted up with a steep flexure in which the overlying Mendola Dolomite participates. There is here a more dominant east-west strike and a dip of ca. 40° N. Vertical cleavage-planes are developed in N. 30° W. direction, which is a leading cleavage system in the dolomite massive above (p. 51). The high wall of Mendola Dolomite is partially covered by vegetation, but lines of stratification are indicated here and there, and the thick sheet of massive Augite Porphyrite which surmounts the crag does not appear to succeed conformably upon the strata.

The most disturbed thrust-slice of the Rodella and Pozzale slopes is that which rests upon the Augite Porphyrite. It is composed of fragments of closely contorted Werfen strata, some parts broken up and embedded in the Porphyrite, others clearly above the Porphyrite and in various relations with the oolitic horizons and Mendola Dolomite (Photo XI.). The thrust-floor of Porphyrite is highly mylonitized and altered, and is interlayered with limestone and dolomite. Patches of Wengen lava also appear, and the rocks are polished and slickensided. Occurrences of dark, basic, intrusive rock are also present, and contact metamorphism has been associated with the pressure changes. The details closely resemble those which characterize the thrust-slice in the same relative position at Cherz Hill (see Plate III.), and I have referred in Part I. to the late inter-

calations connected with the packing of shear-slices on the north and south of the Seiser Alpe (pp. 23-24).

The Mendola Dolomite of the thrust-slice is cut through, almost horizontally, and a streak of Porphyrite occurs in the plane of shearing. The higher slice of Mendola Dolomite is then cut by another shear-plane of very low inclination, at which different horizons of Buchenstein strata and Augite Porphyrite lavas succeed.

W.

E.

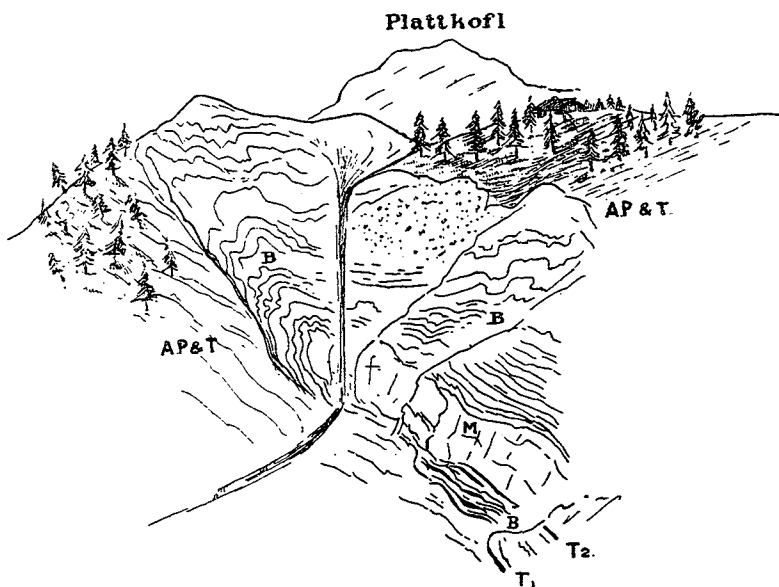


FIG. 24.—Cutting in Pennia (Pegna) Stream: thinning out of the lower horizons in the thrust-mass below the Langkofl and Plattkofl Massive. T_1 . = Thrust-plane between Buchenstein and Wengen horizons. T_2 . = Thrust-plane between Mendola and Buchenstein horizons. M. = Mendola Limestone. B. = Upper Muschelkalk and Buchenstein Strata. AP. & T. = Augite Porphyrite and Tuffs of Lower Wengen Strata.

When the upper slice is traced westward to the Chiarvenna stream the Buchenstein horizons of nodular limestone and Echinoderm Limestone gradually show more fully; they finally appear only as a calcareous streak thinning out between the underlying and over-lying slices of Augite Porphyrite. Still farther west, the lower thrust-mass of the Pozzale ravine thins out in the same way, and the doubling of the Buchenstein and Wengen horizons round the attenuated streak of Mendola rock can be clearly seen, and leaves no doubt that we are here dealing with obliquely overcast plications (Fig. 24). The tuffs

below the lower thrust-slice of Mendola rock are strongly crushed and altered, and may be followed, along with the irregularly bent thrust-plane, through the crags between the Chiarvenna and Pozzale streams. The thrust-plane cuts through higher horizons towards the west, and thus in the east passes below Werfen strata of the thrust-mass.

A band of mixed calcareous and porphyritic agglomerate continues some distance westward, and if the fuller structure had not been disclosed by the Pozzale stream-cutting, it might have been supposed that there was only one disturbed thrust-slice of Augite Porphyrite and Wengen lavas. The outcrop of this shear-plane of agglomerate in the Augite Porphyrite and 'Buchenstein' horizons crosses the Duron Valley, and may be followed through the Mount Donna rocks on the south side of the Valley at *ca.* 1840 to 1900 mètr. contours. On the eastern slope of Mount Donna the lower thrust-plane is exposed where the Werfen strata rest on the Mendola horizons of Col dell' Orso.

Overcasting of Earlier Plications towards South-West.

The simplest interpretation of the series of thrust-slices here would be that they originated owing to compression of the earlier folds towards the south-west, and repeated shearing within the thrust-masses during the long periods of westward overthrusting. The interference effects of north-south plications have been already mentioned, and these plications have affected the thrust-planes themselves (*cf.* p. 22).

Relation of the Pozzale Slopes and Rodella Berg.

(Plate IX.)

Traced eastward from Pozzale, the overthrust Porphyrite continues on the other side of the N.N.E.-S.S.W. fault at a rather higher level in Rodella Berg. The thick shear-breccia below it is cut by this fault, and has only a narrow wedge-like outcrop between the N.N.E.-S.S.W. fault and the east-west fault on the north of Rodella.

Occasional intrusions are present in or near the fault-zone between the Pozzale and Rodella areas. The Mendola Dolomite and Buchenstein limestone form the summit of Rodella Berg, and strongly compressed and slickensided patches of Wengen strata may be observed upon the highest surfaces of the limestone. Small dykes of plagioclastic and augitic porphyrite and diabasic and serpentinous material run irregularly through the limestone.

The Mendola and Buchenstein horizons thin out from the summit eastward, and the Lower Wengen lavas with block-structure, interbedded with Halobia shales, are brought next to the Werfen strata of the thrust-mass. They are thrown down on the north by the east-west fault, between Rodella Berg and Sella Pass, but on the south of the fault there are one or two places where Wengen strata can be seen resting upon the Werfen strata as an overthrust group.

Thus the highest shear-plane in the Rodella and Pozzale slopes is one at which the Wengen lavas have been overthrust above different horizons of the Middle and Lower Triassic rocks belonging to the fractured thrust-mass of these slopes. From place to place along this shear-plane and intersecting faults there are dyke and sill intrusions that have invaded the Wengen lavas apparently at the time of the N.N.E.-S.S.W. dislocations.

The shear-plane below the Wengen lavas is faulted down on the east of Rodella by a north-south fault, so that its outcrop is horizontally displaced towards the south, and may be traced in the hill behind Canazei. The east-west Rodella fault is less displaced to the south, and continues through Pordoi Pass, with downthrow of the Sella area on the north (*cf.* Plate XI.A). The dolomite thrust-slice on the north bends down with steep flexure towards the fault, and is cut by a curved fault round the south, which passes between relatively upthrown Cassian strata belonging to the dolomite thrust-slice at Monte Forca and relatively downthrown Schlern Dolomite, Raibl and Dachstein horizons at Sass Pordoi. The Raibl strata show plicational effects localised within themselves, doubtless owing to the unequal resistance presented by the intermixed series of dolomitic marls and limestone forming the Raibl group, and the dolomite above and below it. Unconformity between the Raibl strata and the Schlern Dolomite is frequently present in the Sella Massive (see Photo X.).

On the south of the east-west fault the underthrust group of Cassian and Schlern Dolomite is bent with steep flexure towards N.N.W., and the Schlern Dolomite of Sasso Pitschi on the south of the Pass trails out towards N.N.W. in the masses of blocks that are gathered below the Sella Massive.

The block-structure that has been developed in the underthrust Schlern Dolomite can be studied in more detail on the north slope of Schlern Berg, where the Schlern Dolomite strata dip below overthrust Cassian strata (Fig. 25).

On the east of Pordoi Pass a series of N.N.E.-S.S.W. faults with upthrow on the east gives sign of the leading cross-arch in which the lower thrust-slices are exposed through the Enneberg, Buchenstein, and Fedaja and Marmolata district. The leading

shear-plane in the Wengen lavas continues on the east through the Chertz Hill and Monte Sief between the St Cassian Meadowland and the Buchenstein Valley. The dolomite thrust-slice of Sella Massive throughout its eastern side forms a well-marked flexure with general north-south axis, and bending westward towards the central band in Sella Massive, and more steeply eastward towards the limiting fault on the east. On both sides the flexure is cut by vertical faults, and these faults unite on the east of Pordoi Pass, continuing southward as the leading

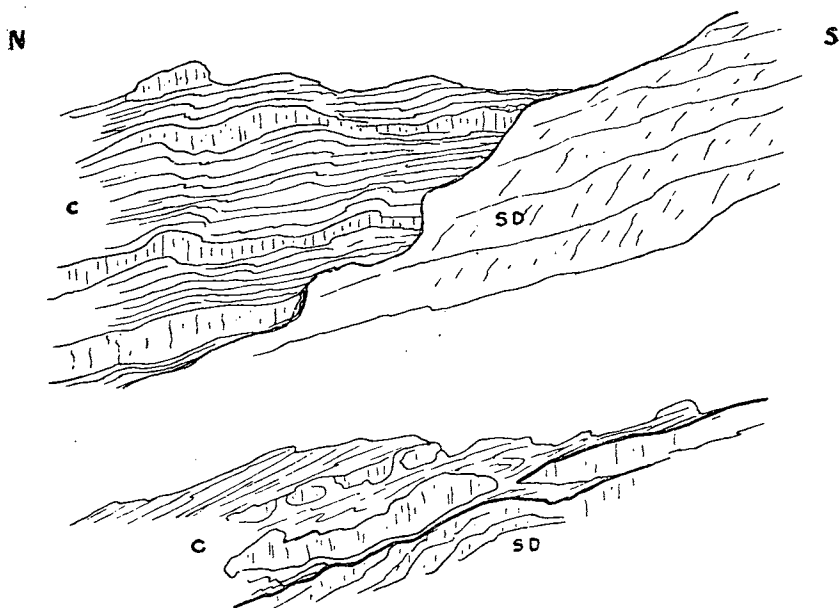


FIG. 25.—Drawings from the north slope of Schlern Mountain, showing the types of structure at the supposed thinning-out of coral reef formation (S.D.) and sedimentary tuffs (C.). Author interprets as local overthrust of the Upper Cassian brown and greenish tuffs with plant remains and interbedded "Cipit Limestones" upon Schlern Dolomite.

N.N.E.-S.S.W. fault between the Marmolata and Bufaure Mountain-Massives (see Photo VII., p. 49).

Thus the geology of the southern slopes below the Langkofl and Sella Mountain-massives confirms the presence of a series of important thrust-slices in this district, and shows the overthrust relation of a massive lower thrust-slice, comprising the Augite Porphyrite lavas, upon the calcareous development of Middle Triassic rocks which is present in the Fassa and Fleims district.

The Pozzale section shows that the thrust-mass is there composed of a group of thrust-slices, and gives evidence of shear-

planes of different ages developed in the thrust-mass. It is fairly evident from the district examined that the older planes have been plicated in N.N.E.-S.S.W. and E.N.E.-W.S.W. directions, and the older crush-zones cut by faults and locally invaded like any other horizon, by the small igneous intercalations and dykes.

The Upper Fassa Cross-Arch (cf. Plate XII.).

Rodella Berg and the Campitello slopes represent the eastern part of the leading cross-arch in the Fassa district, and are much fractured by N.S., N.N.E.-S.S.W., and N.N.W.-S.S.E. faults. The general strike in Rodella and Upper Fassa is W.N.W.-E.S.E., being the reciprocal of the E.N.E.-W.S.W. strike in the Pozzale slopes on the west of the Fassa cross-arch.

We find the outcrop of the lower thrust-mass at very different heights in Rodella mountain. In the highest part of the Rodella arch, the lowest thrust-plane appears at *ca.* 2000 mètr. contour, and the chief shear-planes within the thrust-mass appear at *ca.* 2100 mètr. and 2300 mètr. contours. In the Pozzale slopes, in the west wing of the arch, the outcrops of the same thrust-planes are at *ca.* 1600 mètr., 2000 mètr., and 2080 mètr. respectively. The Fassa cross-arch continues northward through the Ciampinoi to the Pitsch Berg and Sorasas Alpe, and southward through Mount Donna, as shown by the exposure of the underthrust mass in the middle part of the eastern slopes (Plate X.).

In Mount Donna, within the cross-arch area, the main thrust-plane is exposed at *ca.* 1860 mètr. in the Coll dell Orso segment and more than 100 mètr. higher in the middle upthrown segment. Below La Greppa in the Bufaure mountain the highest outcrop of the main thrust-plane is at *ca.* 1860 mètr. At Penia, the main thrust-plane is at the valley level of *ca.* 1550 mètr., and the higher shear-plane below the Wengen lavas crops out as low as 1860 mètr. Again, some distance east, at Chertz Hill in Enneberg and in Buchenstein Valley, the main thrust-plane crops out between 1600 and 1700 mètr. contour and higher shear-plane in the Wengen lavas at *ca.* 1850-1900 mètr. contours.

The differences of height at which the thrust-planes are now exposed can only be explained as the result of the segmentation and plication of the area, and there is convincing evidence in the districts mapped and described, that the thrust-planes were bent towards various directions, and that the system of plication and deformation which affected the thrust-masses was essentially a Torsion-system.

The Pozzale N.N.E.-S.S.W. fault passes through the westward

flexure of the Fassa cross-arch and lowers the western segment, so that the Augite Porphyrite thrust-slice has a wide exposure in Mount Donna. The fault keeps parallel with the flexure at the base of the porphyrite crags and is well-exposed in the Donna valley. It veers from N.N.E.-S.S.W. direction to N.E.-S.W. as it continues southward through Mount Docion; and at Col Pedoi it meets the W.N.W.-E.S.E. flexure and flexure-fault which divides the downthrown east-west band on the north from the upthrown southern area with wide exposure of the basal thrust-mass. This flexure-fault is one which cuts a steep northward inclination of the thrust-plane at the base of the Augite Porphyrite, and is the same which forms the south margin of the Porphyrite in the Bufaure range (Plate XI. c).

The westward and northward flexures coalesce below Mount Docion, but the W.N.W.-E.S.E. fault that cuts the northward flexure turns sharply to N.N.W.-S.S.E. direction and crosses Fassa Valley to the south of the inthrown segment of Augite Porphyrite at Mazzin. The north limit of the Mazzin segment is a fault that also crosses the valley in N.N.W.-S.S.E. direction from the Mount Donna side, where it lowers the Val Donna segment on the west of Col dell' Orso. The Fassa cross-arch is segmented by these small faults, and they limit the chief upthrows and downthrows of the subjacent thrust-masses in W.N.W.-E.S.E. direction. An example of the smaller plications of the subjacent thrust-masses is given in Fig. 26, which also shows the tendency to isoclinal southward structure.

The faults on the east and west of the Fassa cross-arch cut the bent thrust-planes, so also does the fault on the south of Mount Docion and the Bufaure range. The flexure of the thrust-planes makes an angle of *ca.* 50° to the horizontal, and the faults cut almost vertically. The curving of the strike of the faults would, according to these observations, seem to have depended upon the coalescence of a cross-arch and a longitudinal arch, and the definition of local areas of inthrow.

The lower thrust-plane in Mount Donna, at which, above Col dell' Orso, Werfen strata rest upon Mendola Dolomite, may be traced southward through Mendola Dolomite, and causes duplication of the Upper Muschelkalk and Buchenstein group on the slopes of Mount Docion.

*The Outcrop of the Main Thrust-Plane at Mount Donna and
Bufaure.*

I have now traced the chief thrust-planes in the overthrust slices within the area of Fassa and Enneberg, and demonstrated their original continuity. The porphyrite thrust-slice originally

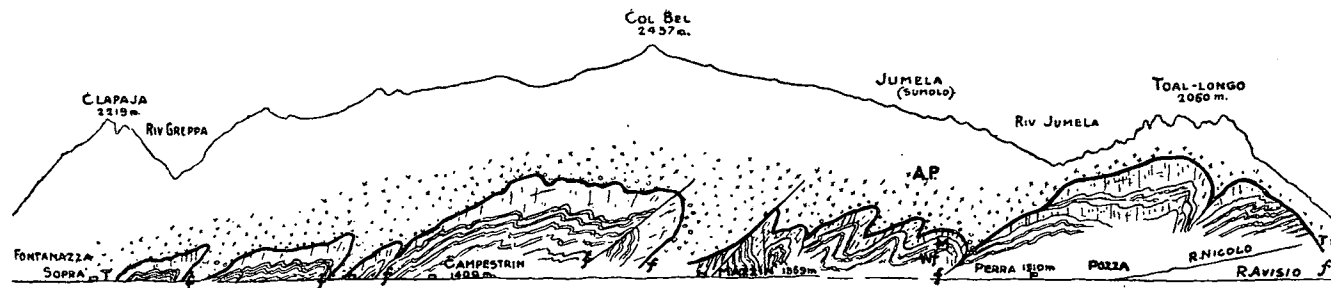


FIG. 26.—West face of Bufaure Massive in Fassa Valley. Plication and southward slicing of subjacent thrust-masses. A.P. = Wengen Porphyrite and lavas of thrust-mass. T. = Thrust-plane. Wf. & M. = Werfen and Muschelkalk of underthrust mass, freely intercalated with dykes at the faults (f.).

extended over the calcareous facies of this region, but has been subsequently lowered against the calcareous rocks at various angles by leading flexures or faults. The marginal outcrop continues from the Fedaja Valley westward on the south of the Bufaure group, and the south of Mount Docion and Mount Donna area to the Schlern (Plates XIa., B, C, D).

As in the case of the east-west Rodella fault, the east-west marginal band of flexure and fault has been displaced considerably towards the south by the same leading N.N.E.-S.S.W. transverse faults which have thrown down the Sella Massive. These two east-west faults of Bufaure and Rodella are step-faults with downthrow on the north, and the series is continued further south in the Monzoni district.

My former paper on the Fassa-Monzoni district showed that the rocks of the Marmolata facies were cut by thrust-planes in that district; thus the basal mass in the Fassa area is itself made up of thrust-slices. For the convenience of the reader I have in my sketch map (Plate XII.) carried the margin of the main thrust-plane below the Upper Gröden thrust-slice through the Fassa district—at Marmolata, Pozza Alpe, Udai, Molignon. At all these places I have made detailed examination of the overthrust rocks, and the geology shows that the Upper Gröden thrust-mass was carried above a plicated floor.

I have also carried the margin of the thrust-plane through Schlern mountain, although I have, as already stated, not made a detailed examination there. Hence I do so only tentatively in order to show how, so far as my present knowledge of the Seiser Alpe and Schlern goes, I think the geological features of the Fassa district are continued there. The dolomitic thrust-slices rest directly upon the basal calcareous facies in several areas in the southern part of the Dolomites. I have not attempted to show these in the sketch-map until I examine specially for the purpose of tracing the outcrops of the thrust-planes.

I have not included the Predazzo and Fleims Valley district, because I am personally unfamiliar with it. But it contains Lower Wengen lavas, and they rest there upon the same calcareous development of Middle Trias as I have mapped at Udai and interpreted as the underthrust mass. The distribution of the Augite Porphyrite can be seen in the geological maps, accompanying the work of Mojsisovics, and also in the recent paper by Dr Philipp (footnote, p. 70). At the time of the Austrian Survey work the Augite Porphyrite was regarded as intrusive in the Predazzo area. Dr Philipp, however, came to the conclusion that the Augite Porphyrite was similar to the lavas in the northern area, and he regarded it as younger than the calcareous rocks upon which it rests. In the Vallaccia

mountain, near the Predazzo district, I observed a thin series of lava and tuff truly interbedded in the calcareous facies and with Wengen-Cassian fossils. But the lavas described by Dr Philipp include thick eruptive sheets of Fassa-Gröden type. What I suggest is, that if in the main the lavas are sedimentary, they may be part of the same thrust-mass which I have demonstrated in the Fassa-Gröden area.

The south margin of the lavas is seen in overthrust position directly above the "Marmolata" or calcareous facies in the Fedaja Valley. Within the downthrown area of Bufaure the outcrop is further south, at Sasso di Rocca, Pozza and Toallongo; again, in the Fassa Valley, where there is a cross-arch, the outcrop of the thrust-plane is exposed at Mount Docion almost due west of its position in the Fedaja Valley. In all cases the Wengen lavas of the Upper Gröden thrust-mass are the horizons that have been carried furthest, and this is explained by the inner structure of the thrust-mass—an example of which is given in the Pozzale and Chiavenna slopes (*cf.* Plate V.). The Wengen strata during the thrust-movements seem to have served as a buffer between the closely plicated and compressed lower thrust-slices and the more extended upper slices.

At the actual thrust-plane the underlying calcareous rocks are waved and there is serpentinous alteration, and the surfaces are often finely polished and fluted. These features may be well observed in the Bufaure Massive, at Mairin Wand on the surface of the calcareous rocks below the Wengen lavas and tuffs of Toallongo. There is only a very thin band, varying from half a foot to a foot, where there could be said to be intermixture of the lava and the calcareous rock, and the compression of this band has been so great that it is practically a compact breccia honeycombed with serpentinous streaks. The thrust-plane is steeply flexured towards N.N.E.-S.S.W. faults (Photo XII.).

At Val Roseal, in the line of the leading N.N.E.-S.S.W. fault on the east of Bufaure, a group of later dykes has ascended, and outrunners have spread into the bedding planes and shear-planes of both the overthrust and underthrust strata. Agglomeratic structure has been locally developed in connection with these fault intrusions. This is the same fault at which still farther south the older Monzonite intrusions in the basal mass have been cut and displaced, these in Monzoni being on the east or upthrow side of the fault.

In this interpretation of the structural features it is easily understood why the Costabella range, which belongs to the calcareous facies, is so freely invaded by dykes and sills connected with the Monzoni Massive, whereas these are almost absent in Vallaccia. For although Costabella and Vallaccia

Col Laz.

Sasso di Rocca.

M.L.

Wg.

Campaz
Alpe.



PHOTO XII.—The Thrust-plane between overthrust Wengen Lavas (Wg.) and underthrust “Marmolata Limestone” (M.L.) in the Bufaure Massive, Upper Fassa; the thrust-plane dips west, towards the N.N.E.-S.S.W. fault at which the lavas of Bufaure Massive are thrown down (*cf.* Photo VII.).

belong to the same calcareous facies, only Costabella belongs to the same upthrow side of the N.N.E.-S.S.W. fault as Monzoni, and has been adjacent to the Monzoni area of intrusion throughout the periods of cross-compression. The Vallaccia Mountain at the chief periods of the dyke intercalations would have been considerably to the north of the Monzoni area.

Differential Horizontal Movements along the N.N.E.-S.S.W. Faults.

The whole group of N.N.E.-S.S.W. faults in this area is distinguished by slickensided fault surfaces, and at several of them I have observed an absolutely horizontal direction of the slickensides. This indicates that horizontal displacements in N.N.E.-S.S.W. direction have taken place along these faults. These displacements have taken place subsequently to the overthrusting, so that the ramifying dykes which so freely intercalate the faults and cleavages and all horizons of the sedimentary strata in the Monzoni Alpe and Costabella Mountain belong, as I have previously demonstrated, to an advanced period in the deformation of this district.

Old Fissure Facies and Later Intercalations.

These dykes are distinct from the older Monzonite mass which was severed by the faults into which these later intrusions passed. They are also distinct from the lavas and tuffs which are incorporated in the sedimentary succession of the Upper Gröden and Fassa thrust-mass. This thrust-mass was only invaded by igneous material connected with the Monzoni area after it had been by thrusting and faulting brought into positions above, or in connection with, fissures in the basal mass.

In the Bufaure Massive, the Werfen and Mendola Dolomite horizons of the thrust-slice are locally exposed, and in varying degree brecciated with the Augite Porphyrite rocks belonging to the thrust-slice. On my first examination of the Bufaure Massive I had only made detailed observations at the periphery where the Augite Porphyrite is intrusive in the lower Trias. But on more complete examination of the central part of Bufaure I found there a succession of Wengen lavas and tuffs such as I was familiar with in the Sella area. In the succession forming La Greppa it is clear that the thick sheet of Porphyrite underlying true plant-tuffs extends continuously downward to the agglomeratic part of the Augite Porphyrite which is intermixed with the lower horizons of Trias belonging to the Upper Gröden thrust-mass, and penetrated by intrusive material.

The dark Wengen tuffs above this lower sheet are like those of Auf der Schneid ridge on the south of Fassa Joch, and pass upward into higher lavas which show well-marked block-structure. The tuffs and block lavas are the same horizons which are next the east-west fault-plane at Rodella, and they are likewise here faulted down on the north of the La Greppa east-west fault—which is continuous with a fault in Fedaja Valley.

A dyke follows this fault, and the Werfen strata and Mendola Dolomite adjacent on the south are full of dykes and sill-ramifications, passing into joints, cleavages, and bedding-planes.

The main stratigraphical feature of the overthrust mass in Bufaure is that the Wengen lavas rest upon a fragmented succession of Buchenstein, Mendola and Werfen horizons, only locally left in a recognisable sequence, generally brecciated with the porphyritic rock material. And this thrust-mass with its floor-breccia of patches of older Trias reposes upon the calcareous rocks of the basal thrust-mass, and has been plicated along with them in east-west and N.N.E.-S.S.W. directions. It has been lowered by flexure faults surrounding it on every side except on the north-east.

PART IV.

GENERAL CONCLUSIONS.

- (1) East-West Inthrow Band of Gröden and Enneberg—(2) Upper Gröden and Fassa Thrust-Mass—(3) The Dolomitic Thrust-Masses—(4) Basal Mass—(5) Differences of Triassic Facies—(6) The Marginal Flexures and Faults—(7) East-West Plication of Thrust-Masses before their Overthrust—(8) Plication of Subjacent Thrust-Slices—(9) Overcasting of Earlier Plications and Isolation of Segments—(10) Deformational Structures—(11) Westward Thrusting—(12) Intrusions in Subjacent Thrust-Slices.

(1) *East-West Inthrow Band of Gröden and Enneberg.*

The wide syncline including the Dolomite Massives of Langkofl, Sella and Sett Sass is a fault-segment on the downthrown north side of a leading east-west fault which may be followed from Mahlknecht and the Rosszähne to Rodella, and to Cherz Hill and Monte Sief in Enneberg.

(2) *Upper Gröden and Fassa Thrust-Mass.*

The lower horizons within this fault-segment belong to a widely extended thrust-slice from the east, which may be called the Upper Gröden and Fassa thrust-mass, as its western margin in the Dolomites is in that area. The rocks of the thrust-mass next the thrust-plane are sometimes porphyritic and tufaceous