[SU]NDRY GEOLOGICAL PROBLEMS

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CHRISTIANIA

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On October the 1st, 1902, the writer sent a telegraphic report to the newspapers in Christiania »Morgenbladet«, »Aftenposten«, and »Verdens Gang« on »The Iron Ore Deposits in Sydvaranger, Finmarken, Norway, and Relative Geological Problems« which has since been reproduced in the Lake Superior number for August 27th, 1904, of the »Mining World«, Chicago, in »La Revue Noire«, Lille, for January 15th, 1905, in »L'Écho des Mines et de la Métallurgie«, Paris, for December 5th, 1904, in »Zeitschrift für der Berg-Hütten- und Salinenwesen« 1905, page 19—21, in »Engineering and Mining Journal«, New York, for February 24th, 1906, and in »Oesterreichische Zeitschrift für Berg- und Hüttenwesen« No. 13, 1906. Refering to this report the writer wishes to submit the following as the conclusions from the geological observations which he has since then been able to make here in Norway:

The socalled Devonian sandstone at Krokkleven and Sundvolden, Ringerike, which has been parallelized with the »Old Red« of the British isles is an igneous rock: it is the sheeted pendant of the superposed chocolate coloured rhombe-porphyry. Its »ripple marks« are curved-faced jointing planes. The conglomerate found about the transition point from porphyry to red sandstone also is an igneous rock. The »pebbles« partly can be recognized as crystals, imperfect and rough as they are and with rounded surfaces. They are also largely flattened, especially is this the case where the conglomerate shows rudimentary lamination. »Pebbles« flattened parallel to the lamination will then be found lying in rows along the bedding-planes. It may be that the red sandstone does not show exactly the same chemical composition as the porphyry; but this would not signify, because sheeted portions of eruptives usually differ in composition from adjacent and contemporary crystalline parts of the same. Thus for instance quartz, calcspar, ores and carbon show a tendency to diffund toward sheeted portions of igneous rocks and give them a composition different from the rest. Also sheeted zones of pressure are frequently »sericitized«, »kaolinized« or »propylitized«. Conglomerates are often found on the boundary between the sheeted and crystalline facies of an eruptive, also marking the boundary between two systems of differentiatory lamination at angles to each other. Hence the frequent occurence of »bottom conglomerates«. Each »pebble« of a conglomerate often is found to be the center of concentrically sheeted matrix. Near Krokkleven I have found concentric pressure-zones in the porphyry enclosing blocks of porphyry looking like huge waterworn cobble stones. The lumps of crystalline gabbro at the Röros mines of cupriferous pyrites, between which gabbro and concentrically laminated eruptive the ore is usually found, have a smooth surface and the form of hogs-backs and potatoes.

At Sundvolden, Ringerike, the same force which brought about the border-sheeting of the eruptive field of which the rhombe-porphyry is a part, has also been the occasion of the more or less differentiatory lamination of the fossiliferous sediments through which the eruptive has burst up, or rather the sediments have been differentiatorily laminated through heat and lateral pressure from the eruptive, and at the same time the border-zone of the eruptive has become sheeted by the reaction. The cooling effect from the sediments together with the raising of the melting point of the eruptive border through reactive pressure from the sediments, have combined to accelerate the solidifying of the eruptive border, thereby causing the fine grained, more or less clastic, structure of the same and its bedded state vertically to the direction of the reactive pressure. The igneous »sandstone« and the Silurian sediments are now found conformably »stratified« and are gradually merging one into the other, and both are dipping under the rhombe-porphyry. The jointage of the granite at Eidanger, near Porsgrund, is conformable to the »stratification« of the adjacent Silurian, and they gradually merge one into the other, partly because the jointing of the granite is accompanied by closer grain, partly because the sediments adjoining the granite have been in a state of fluidity increasing with the proximity to the molten granite. Such a process of differentiatory sheeting of sediments largely resembles the analogous differentiatory lamination of igneous rocks. Sediments in a half molten and igneous rocks in a half cooled state under peculiar conditions of pressure will behave alike. Special conditions of heat and pressure will put sediments in a state of fluidity sufficient to allow of a very extensive rearrangement of substance, at the same time as they remain solid enough to prevent all traces of organic life from being obliterated. By strong and regular differentiatory sheeting of sediments the fossils contained are largely obliterated; certain of the beds formed by the lamination are comparatively intact and show the fossils well; other beds formed by the lamination of sediments under heat and pressure have been entirely liquified and appear, as if they should be constituted of originally igneous matter. The first stage of the differentiatory lamination of calcareous fossiliferous sediments, as at Ringerike, give them a certain nodular structure, in the next stage they show lenticular lime-balls in regular rows, in the next stage the marl-balls have as it were coagulated into bands of calciferous matter, in the next stage these bands of hard calciferous matter are very thick and well defined and have as their compliment proportionally wide series of thin shale. The original sediments will be found relatively intact under certain conditions of several crossing directions of lamination. Thus for instance I found near Sundvolden three crossing systems of lamination enclosing a wedge of sediments with fossils relatively very well preserved. As an analagon from differentiatorily laminated eruptives I may mention that at Lottivara and Lemmivara, in Laxelv in Finmarken, at numerous places right in the middle of hornblende schist three crossing directions of jointage are found to enclose a pyramid with the point down, consisting of crystalline gabbro often carrying in the middle of it a lump of native copper. Thus I have found such a tetrahedric wedge of gabbro, less than a third of a cubic foot in all, enclosing a lump of native copper weighing half a pound, and such wedges of gabbro would be found in quite isolated positions here and there in the hornblende-schist. Where such nearly unaltered portions of relatively calcareous, fossiliferous matter were found, they showed the original fossiliferous sediment to have been an amorphous mass without any stratification and consisting of corals and shells of other marine animals imbedded in a mud. Where pure fossiliferous limestone is now found, it is partly made up of the original fossils in situ, but the balance of the lime has come there by replacement. That replacement of substance can take place to a very large extent without obliterating the fossils contained in the sediment can be seen at the hematite mines at Clinton in New York state: in the socalled fossil ores the fossils as well as the mud in which they have been imbedded have all been turned into hematite ore.

Similar instances can be had from the hematite deposits in Cumberland, where brachyopodes and corals have been converted into hematite retaining their form. By Konerudkollen zinc mines near Drammen one finds corals filled with crystals of idocrase. Ore deposits are largely formed by diffusion and migration of igneous emanations of metalliferous matter having taken place within the sediments adjacent to an eruptive according to laws analogous to those obtaining for the segregation of ores within eruptives. Thus effects of pressure play a similar role also for ore deposits in sediments. The sediments have been able to get into a state sufficiently fluid to allow of the migration of metalliferous particles, but not sufficiently fluid to obliterate all the fossils.

The »post-silurian« eruptives of the Christiania district, geologically speaking, have their porphyric rim and their border sheeting, in red sandstones as at Krokkleven and Holmestrand or in dark hornblendic slate as at Krekling, Eker. The sediments of the Christiania territory having been differentiatorily laminated through the agency of heat and pressure from the very large »post-silurian« field have afterwards been altered into alum shale in the regions nearest to the »Archean«, under the influence of heat and pressure from the latter (the Archean) which is of igneous and comparatively recent origin. The »Archean« has partly altered the previously laminated »Silurian« sediments nearest to it into alum shale, partly it has melted these sediments forming the socalled Oslo porphyry (formerly also called oligoclase-porphyry, eurite porphyry or felsite porphyry). The fossiliferous ellipsoides of »stink-kalk« contained in the alum shale have got their ellipsoidic form and their contents of bitumen, hydro-carbon, through the eruptive action of the »Archean« upon limestone beds previously existing. The same action of the »Archean« accounts for the contents of the alum shale in carbon, the bitumen of the lime ellipsoides and the carbon of the alum shale being volcanic products diffunded from the magma of the »Archean«. Alum shale and Oslo porphyry are often found to merge one into the other. At Vikesund, Modum, the Oslo porphyry stands up in the alum-shale as a wall parallel to the boundary plane between the alum-shale and the »Archean«. The conglomerate at Fure north of Vikesund is found forming the transition between the eruptive »Archean« and the sedimentary alum shale. This conglomerate at Fure is one of the most remarkable geological occurences in Norway.

The most striking instance of differentiatory lamination of igneous rocks through effects of pressure in cooling that I know of is the socalled Ottfjäll diabase from the Ottfjäll mountain in Jämtland, Sweden, and described by Professor P. I. Holmquist in the transactions of the geological society of Stockholm, vol. 16 (for 1894, page 175). The sandstone formation of Dalecarlia consists of sandstones, conglomerate, and »intrusive« diabase beds. All these rocks are igneous, and the formation is a product of the differentiatory lamination of a cooling magma through pressure, such as has been the case by the above mentioned Ottfjäll diabase. Certain beds formed by the differentiatory lamination of the Christiania sediments have become melted in the process and are now found as layers of diabase following the »stratification« of the sediments and merging by imperceptible gradations into the same.

Sheets of molten rock which have been considered as intrusive eruptives are found all over the world as one of the products of the differentiatory lamination of sediments through heat and pressure from eruptives of the neighbourhood. As instances can be given: the toadstone of the Derbyshire lead mines, the celebrated Whin Sill in the North of England, the diabase beds in the iron mines of Pervukhina in Southern Ural, Russia, the younger »Schalstein« and diabase-amygdaloid of the Büchenberge iron mines near Elbingerode, Harz, the grey porphyry at White Cap chute, Leadville, Colorado, the porphyry of the Eagle river mines, Eagle county, Colorado, the Eagle Hill porphyry at Mercur, Utah, the Leadville white porphyry, the white porphyry of the London mine in Mosquito gulch in Colorado, the »white porphyry« (diorite) on Aspen Mountain, Colorado.

The results of the borings for coal at Andöen in Nordland go to show that the Tromsö marble-mica-schist group or the »Archean«, whatever it would be called, of this part of Norway is younger than Brown Jura. The bitumen forming the chief constituent of the coal found there is an igneous emanation from the eruptive below.

Good mines are proverbially watery. This is easily explained, because ores have had a general tendency to diffund to zones or localities of stress, pressure, jointing, shearing and shattering within eruptives or adjacent sediments. »Lettengänge« often carry ore. Both genuine »Erzgänge« and pyrites deposits of the Vigsnæs type very often have »gouge«, »selvage«, »gangletten«, »salbänder« accompanying the ore, which is one fact to indicate the common genetic origin of »Erzgänge« and lenticular deposits of pyrites as found at Vigsnæs and many other places. At Rödklev mine (situated about one kilometer from old Vigsnæs mine) going through one of the crosscuts worked vertically on the »stratification« one can step by step follow the saussurite gabbro, passing by imperceptible gradations through foliated fine-grained gabbro and green chlorite schist to clayey matter, »Gangthonschiefer«, in lenticularly shaped inclusions within the green schist. The normal crystalline saussurite gabbro has little or no regular jointing; as regular jointing comes in, the minerals of the gabbro get a certain orientation parallel to the jointing; as the jointing planes get closer and closer, the foliated gabbro gradually passes into green chlorite-schist, and by very strong and close lamination the chlorite-schist gradually passes into fat clayey matter. Thus this clay is, as it were, the final stage of laminated saussurite gabbro. Jointing planes are a product of contraction by the solidifying of a molten magma. Where such solidification is precipitated by stresses, jointing vertically to the direction of the pressure will be the result, also finer grain and a certain more or less pronounced orientation, parallel to the jointing, of the crystals formed. Clastic structure also often is found as the result of solidification precipitated through strains and stresses. Jointage and related phenomena are common in sedimentary as in igneous rocks, which shows that contraction has taken place also by the passing of the first-mentioned from the semifluid into the solid state.

Ores are preferably found in pressure-zones, because metals have a tendency to diffund towards the portions of a magma that consolidate first.

The Christiania valley is traversed by an extensive system of diabase dykes running NW.—SE. These dykes are not originally igneous, consisting of molten matter from the sediments and being formed through the agency of pressure-forces (»Druckkräfte«) acting normally to the strike of the sedimentary »strata«. The »dykes« of diabase, locally called blåbest, at Konerudkollen zinc mines near Drammen are of sedimentary origin, the Silurian having been partly melted by heat from the underlying granite in zones with peculiar conditions of stress or pressure. These same conditions have also tended to favour the deposition of ore diffunding from the underlying »post-silurian«

granite into the »Silurian« floating on the top of the granite. The rhombe-porphyry at Tyveholmen in Christiania also is melted sediment.

Concentrically laminated portions of foliated eruptives usually are found to enclose very heterogenous masses of rocks of extraordinary composition: pegmatite, ores, dolomite, conglomerates, etc. Instances are: The iron deposits on Langö island by Kragerö, the norite field by Ertelien, Ringerike, with its contents of nickeliferous pyrhotite, the Storgrufva mine at Persberg, Sweden, Åmmeberg zinc-mines in Sweden, Pitkäranta in Finland, Gap nickel mine, Lancaster county, Pennsylvania. The Sudbury nickel district in Ontario, Canada, offers an instance of concentric lamination of eruptives on a colossal scale. The elliptic or perhaps ellipsoidal lamination here encloses a socalled Cambrian field of peculiar rocks that have been called vitrophyre tuffs, gray clayey sandstones and black slates. In the black slates are found irregular veins of anthraxolite. Somewhat similar geological conditions as in the Sudbury district, although everything is on a much smaller scale, obtain by the Langsev—Thorbjörnsbo iron-ore field at Arendal, Norway. See »Nyt Magazin for Naturvidenskaberne«, Volume 11, for 1861.

Nickeliferous pyrhotite is often found in the company of norite; but the nickel ore at Ertelien, Ringerike, has no more been magmatically segregated out of the norite, than gold has been magmatically segregated out of the quartz of a gold-quartz-vein. Still less are the Sudbury nickel deposits segregated out of the occurences accompanying them of norite which are often very small.

Semicircular lamination of eruptives and sedimentary rocks equally with concentric lamination has favoured ore deposition. It seems as if the forces at work to cause irregularities in the differentiatory lamination have served also to attract ores to their locus of activity. As instances of ore segregations accompanying semi-circular or irregular lamination can be given: The Dunderland iron ore deposits, Witwatersrand banket in Transvaal, the Marquette iron ore mines Lake Superior, Schmiedefeld iron mines near Gräfenthal in Thuringia, Eisenerz iron mines in Austria, the saddle reefs of Bendigo, Australia, Broken Hill, New South Wales, Rammelsberg by Goslar, Harz, the pyrites mine at Meggen on the Lenne, Germany, Paulus iron mine at Moravicza, Hungary, Low Moor iron mine, Virginia, Cherry Valley mine, Missouri, Franklin Furnace zinc mine, New Jersey.

At the Fehn iron mines, near Ulefos, the dolomite is found to pass into granite by transitional stages showing all gradations. The limestone called Hedekalk in Sweden and Biridkalk in Norway are also of igneous origin. By the differentiatory lamination of sediments they have largely been charged with foreign substance which emanating from the active eruptive has been deposited in the sedimentary socalled »strata« by replacement, or whatever one would call a process which evidently has much in common with the processes of magmatic segregation and rearrangement of substance which are observed to have taken place within igneous rocks. While sedimentary limestone beds will partly have got the lime from fossils in situ and from lime of organic origin concentrated into the limestone beds from other parts of the sediment, dolomite is an igneous product, diffunded into the sediments from the eruptive, settling there by replacement; so also is the greater part of the carbonic substance constituting the coal-seams. Only part of the carbon in the coal-seams is of organic origin, the rest has come from the nearest eruptive wandering into the sediments and has settled there according to laws which are, at least at present, hard to understand. The fire-clay following the coal-seams give one indication of their genetic origin, same as »Gangletten«, gouge and kaolin afford one indication of the ordinary genetic origin of ore deposits. If the coal in the coal-seams is largely an emanation from eruptives, it follows naturally that petroleum and natural gas must also be volcanic emanations.

The copper bearing shales of Mansfeld have been formed genetically on somewhat the same lines as a coal-seam (they also contain carbon), the copper having diffunded into the sediments from the nearest underlying eruptive. (Such diffusion is not entirely inexplicable on everyday actual experience. In two pieces of two different metals in close contact metallic substance will sometimes diffund from one piece into the other at ordinary temperature, when sufficient time is allowed for the process.) At Mansfeld also cross-pressure, indicated by the system of strong joints locally called »Rücken«, is found to have influenzed ore deposition. However it is not sure that the systems of cross-jointing so common in coal-mines has not also influenzed the deposition of carbon.

Most of the ore deposits of the world owe their existence to eruptives. They are with few exceptions either found as segregations within eruptives or as emanations from such eruptives deposited in neighbouring sediments.

By the differentiatory lamination of sediments the fossils contained in the same sediment have had variable fates according to their different chemical compositions and to the special kind of replacement which has taken place at the particular spot where each fossil has been located. Some of the »strata« produced have become melted. In these »strata« and many others the fossils have been entirely obliterated. Lime-shells have fared the best in zones of calcareous replacement, also they have fared well in localities of iron-ore replacement. Parts of plants have had the best chances of preservation in the zones of carbonaceous replacement, that is to say in the coal-seams. On the other hand it seems likely that the carbon of volcanic origin has had a tendency to diffund towards localities which have already been rich in vegetable matter, thereby making the frequency of fossil plants in the coal-seams more pronounced. Fossil wood often is found in a state of good preservation by silicious replacement. In the Leeds mine, near the South East corner of Nevada, horn-silver has diffunded to and impregnated vegetable remains such as wood, twigs and leaves. The nature of the fauna and the flora as found in a sedimentary »stratum« is then chiefly determined by purely accidental circumstances, and the historical part of geology, palæontology, and palæobotany has to be revised.

The position of the small remnants of fossiliferous sediments that have escaped the universal destruction occasioned by the eruptive upheaveals that have made Fennoscandia goes to show that this gigantic volcanic activity has taken place in stages, and that the outburst of the »Archean« marks the last stage of this activity. The Thelemarken formation represents the surface development and the Bamble formation the border facies of the great »Archean« eruptive field, and they are both highly differentiated, same as the Huronian and Algonkian facies of the great »Archean« eruptive field of tertiary age in Canada.

It has been remarked that the great lakes have been the making of the United States. If that is so, it is the sheeting of the border of the large Northern American »Archean« eruptive field in contact with equally sheeted adjacent sediments which has been the making of the great lakes. Also the sea between Jutland and Norway, the gulf of Finland, lake Ladoga, lake Onega and the White

Sea owe their existence to the sheeted, by erosion easily destructible, condition of the border of the Fennoscandian »Archean« in contact with equally strongly sheeted sediments.

Some of the richest mines in the United States, the Lake Superior iron mines and the Lake Superior copper mines, are found about the contact of the great North American eruptive »Archean« field with the sediments to the South of it.

The Alps and the Himalaya have been formed by the eruption of the »Archean« in the tertiary age.

Christiania, July, 1906.

G. Henriksen.