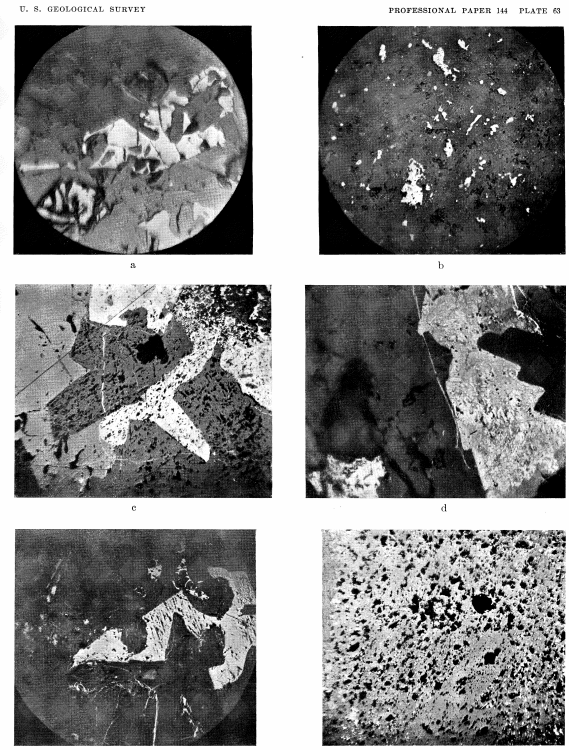
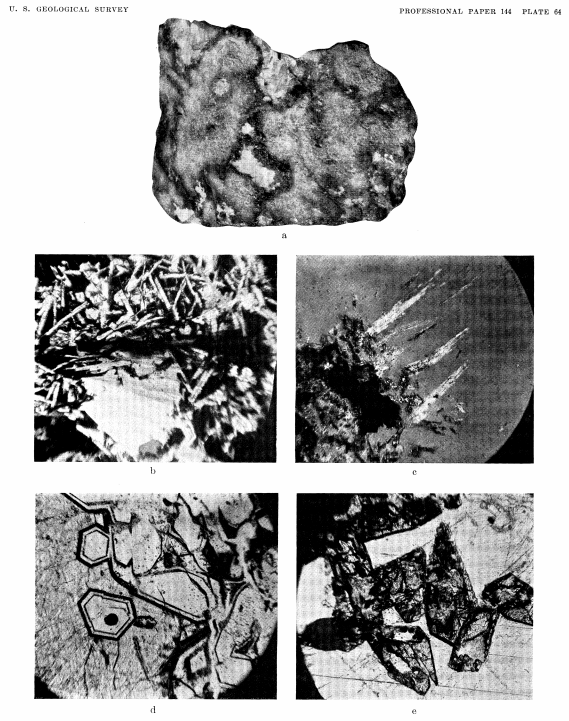


IRON OXIDES IN ROCKS AS SEEN IN POLISHED SECTIONS

a, Unaltered magnetite from the Greenstone, olivine partly altered, ×82; b, f, hematite in felsite pebbles from the Calumet Hecla conglomerate, ×115; c, magnetite largely altered to hematite, trap above Isle Royale lode (note strings of excess hematite), ×115; d, magnetite altering to hematite, middle of second flow below Calumet Hecla conglomerate, ×158; e, titaniferous magnetite altering to hematite, ×228. All enlargements approximate

[PLATE 63. Iron oxides in rocks as seen in polished sections.]



ALTERATION AND REPLACEMENT OF MINERALS

a, Red feldspar (dark areas) replacing amygdaloid, light areas quartz and carbonate, Mass mine; b, prehnitization of feldspar, ×60; c, pumpellyite in quartz altered to sericite, ×200; d, quartz and calcite along Ahmeek mass fissure (note zonal growth of quartz), ×30; e, epidote in calcite altered to chlorite (centers of crystals alter most readily), ×76. All enlargements approximate

[PLATE 64. Alteration and replacement of minerals.]

The results of the two groups of analyses are represented graphically in Figure 4. The noteworthy features are (1) the higher percentages of total iron both at the top and toward the bottom of the flow, that at the top being the highest; (2) the steady increase in ferric iron from bottom to top, with a sudden increase in rate in the upper 20 feet—that is, in the brecciated amygdular top; (3) the increase of total iron at the top associated with an increase in ferric iron, but the increase in total iron in the bottom third of the flow associated with a slight decrease in ferric iron.

Five pairs of complete rock analyses are available for a contrast between the oxidized tops and the deeper unoxidized parts of the corresponding flows of Keweenawan lavas. These analyses are further discussed under "Weathering" (p. 40), especially 5a and 5b, which are the only ones that have been studied by the writers.

Analyses of upper and lower parts of Keweenawan flows

	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b
SiO_2	45.83	49.40	46.78	46.66	47.74	42.71	45.70	46.22	47.0	43.6
Al_2O_3	18.92	16.12	17.04	16.97	16.75	14.93	20.44	10.22	20.8	18.0
Fe_2O_3	6.02	11.51	7.95	9.52	2.55	7.45	9.50	12.88	6.6	14.5
FeO	6.24	2.13	6.31	4.16	6.31	3.45	8.95	7.45	4.2	.4
Total Fe	9.06	9.71	10.46	9.90	6.69	7.92	13.60	14.81	7.88	10.46
MgO	8.49	3.52	6.31	5.02	8.32	2.70	2.24	.84	4.3	3.4
CaO	9.28	10.90	6.94	9.37	11.40	22.76	7.46	15.56	11.8	12.0
Na_2O	2.10	3.02	3.44	4.08	1.93	.54	.80	.18	?2.7	?3.9
K_2O	.32	.58	1.10	.44	.14	.04	.28	1.04		
H_2O-	.50	.10	.66	.91	2.73	3.56	.35	.58	?3.0	?4.1
H_2O+	2.70	2.30	3.62	2.79			2.78	3.91		
TiO_2					1.02	1.29	1.10	.95		
CO_2	.10	.59	.08	.02						
Cu	.01?	.04							.03	.04
MnO					.52	.22				

1a. Specimen 47500, country rock 70 feet from the lode, seventh level, Winona mine, Michigan.
1b. Specimen 47499, center of lode, same locality as 1a. Analyses 1a and 1b by R. D. Hall, Univ. Wisconsin.
2a. Specimen 47506, 12 feet from footwall of 63d level of Quincy mine, Michigan.
2b. Specimen 47505, footwall near lode, same locality as 2b. Analyses 2a and 2b by R. D. Hall, Univ. Wisconsin.
3a. Melaphyre, lower zone of bed 64, Eagle River section, Michigan.
3b. Prehnitized upper zone of bed 64, same locality as 3a. Pumpelly, Raphael, Metasomatic development of the copper-bearing rocks of Lake Superior: Am. Acad. Arts and Sci. Proc., vol. 13, p. 289, 1878.
4a. Fresh basaltic rock from center of flow, 15 feet from lode, Dingle Creek mine, Douglas County, Wis.
4b. Superjacent amygdaloidal lode, same flow as 4a. Analyses 4a and 4b by W. G. Wilcox, Univ. Wisconsin.
5a. Kearsarge amygdaloid lode, 81st level, Calumet & Hecla mine.
5b. Same, specimen from top 4 inches of lode. Analyses 5a and 5b made at mill laboratory, Calumet & Hecla Consolidated Copper Co.
Analyses 1a to 4b are quoted from Van Hise, C. R., and Leith, C. K., U. S. Geol. Survey Mon. 52, p. 583, 1911.

From these pairs of analyses, each of which shows an increase of ferric iron and a decrease of ferrous iron toward the top and all but one of which show an increase in total iron upward, certain inferences may be drawn in regard to other changes that accompany these increases in iron and oxygen. Frequent reference will be made to these analyses in the ensuing discussion. It must be borne in mind that the analyses represent the composition of the rocks after they have been affected by many kinds of alteration in the period that has elapsed from the time of lava outflow to the present day, and that in the top or amygdaloidal portion of the flows the combined effect of alteration has been, as a rule and perhaps without exception, much greater than in the trap. Only the specimens represented by 5a and 5b have been studied by the writers, and the discussions are based primarily on these, but the application to the other analyses is pointed out. Samples 5a and 5b were selected from rock that showed the least effect of the mineralizing solutions. Explanation of some of the features of the other analyses could be ventured only if the nature of the material were known.

MINERALOGIC FEATURES

The mineralogic expressions of these variations in oxygen and iron content are mentioned, so far as the traps are concerned, in the section dealing with alteration (p. 34), as the changes evidently affect rock minerals previously crystallized. But beyond the partial or complete conversion of olivine and magnetite to hematite, the trap seems to be in the same state as when first crystallized, and there is nothing in the rock itself to suggest that it crystallized under abnormal conditions. The significant mineralogic features