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No.	Symbol	Name	r	Symmetry	Example	Crystal System
9	IIIMu	Trigonal pyramidal	1	A_3	$NaIO_4.3H_2O$	Trigonal
10	IIIMc	Rhombohedral	2	A_3C	Penacite	Trigonal
11	IIIMh	Trigonal trapezohedral	2	A_33A_2	α-quartz	Trigonal
12	IIIDu	Ditrigonal pyramidal	2	A_33P	Tourmaline	Trigonal
13	IIIDc	Hexagonal scalenohedral	4	A_33A_23PC	Calcite	Trigonal
14	IVMv	Tetragonal bisphenoidal	1	(A_4)	$Ca_2Al_2SiO_7$	Tetragonal
15	IVMu	Tetragonal pyramidal	1	A_4	Wulfenite	Tetragonal
16	IVMc	Tetragonal bipyramidal	2	A_4PC	Scheelite	Tetragonal
17	IVMh	Tetragonal trapezohedral	2	A_44A_2	$NiSO_4.6H_2O$	Tetragonal
18	IVDv	Tetragonal scalenohedral	2	$(A_4)2A_22P$	Chalcopyrite	Tetragonal
19	IVDu	Ditetragonal pyramidal	2	A_44P	$AgF.H_2O$	Tetragonal
20	IVDc	Ditetragonal bipyramidal	4	A_44A_25PC	Zircon	Tetragonal
21	VIMv	Trigonal bipyramidal	1	(A_3P)	none	Hexagonal
22	VIMu	Hexagonal pyramidal	1	A_6	Nepheline	Hexagonal
23	VIMc	Hexagonal bipyramidal	2	A_6PC	Apatite	Hexagonal
24	VIMh	Hexagonal trapezohedral	2	A_66A_2	β-quartz	Hexagonal
25	VIDv	Ditrigonal pyramidal	2	$(A_3P)3A_23P$	Benitoite	Hexagonal
26	VIDu	Dihexagonal pyramidal	2	A_66P	Iodyrite	Hexagonal
27	VIDc	Dihexagonal bipyramidal	4	A_66A_27PC	Beryl	Hexagonal
28	4IIIMu	Pentagonal tristetrahedral	1	$4A_33A_2$	Ullmanite	Isometric
29	4IIIMc	Diploidal	2	$4A_33A_23PC$	Pyrite	Isometric
30	4IIIMh	Gyroidal	2	$4A_33A_46A_2$	Cuprite	Isometric
31	4IIIDu	Hextetrahedral	2	$4A_33A_26P$	Tetrahedrite	Isometric
32	4IIIDc	Hexoctahedral	4	$4A_33A_46A_29PC$	Galena	Isometric

STREAM AGGRADATION THROUGH IRRIGATION

By Albert B. Reagan

Cornfields, Ganado, Arizona

The workings of man as a geological agent is nowhere perhaps so well extensively displayed as in that land of little rain, the arid Navajo Country in northern Arizona. The results are now already so conspicuous that some travelers in the region ascribe the products to the notable secular changes in climate or to other secular operations of the geological processes. The effect to which attention is here directed is the wonderful aggradation of the desert drainage ways because of the extensive or complete diversion of the sporadic waters for irrigation purposes. These irrigation operations are in action for several hundreds or even thousands of years; and the effects are capable of quantitative measurement.

In a rather whimsical little sketch[1] captioned "Man's Completion of Nature's Supremest Effort on the Great Plains," Keyes recently gives emphasis to the seemingly curious phenomenon of stimulated desiccation of a region through utilization of streams for irrigation. Bearing upon the anomalies of climate and increasing influences of epirotic deposition he tersely observes that, "Ever since early Miocene times, as the geological records disclose, there has been a strong tendency for the Great Plains to grow higher in place of lower. The contest to push back the streams, to completely eliminate them from the region, to extend the western deserts farther eastward, has gone on steadily until the number of rivers which at present take origin in the Rocky Cordillera and the waters of which still reach the sea, may now be counted on the fingers of one hand. The efforts of desiccating climate to dry these rivers up, of thirsty soils to drink them in, of their own excessive sediments to choke them, of desert

[1] Journal of Geography, Vol. XIV, pp. 257-259, 1916.

maze of lateral, straight-walled chasms fifty feet or more in depth. And the Tokas Jay, the stream leading northward up the valley along the road to Marsh Pass from Moenkopi Wash, and that of Pueblo Colorado Wash at Ganado, 45 miles west of Fort Defiance, Arizona, will cut up those valleys and destroy their lakes and pools, as Laguna creek has done in the Kayenta region, unless man brings about some means to stop their devastating process.

Huntington and Gregory, agree in believing that the aggrading of the valley floors of this region was due solely to climatic changes — little rain fall, and the action of the wind. They also believe that the cutting of the valley fillings is due to the overgrazing of the region and the making of paths and roads.[8]

"During the last twenty years in consequence of overgrazing and probably, too, of climate change, the alluvial floors of canyons and washes (of the Navajo country) have been trenched by streams, and the normal valley profile has been changed from a flat-floored, rock-walled gorge to a valley, including an inner canyon ten to fifty feet deep, whose walls are of alluvium. . . . This new development has resulted in enlarging the amount and increasing the permanence of stream flow. A number of perennial springs and seeps issuing from the base of the alluvium in the newly made canyons and arroyas have been added to the reservation within the last thirty years, and the amount of surface water has been increased accordingly at the expense of the ground-water supply."

Gregory further observes: "The nature of the change in physiographic environment that called a halt in the work of rock canyon cutting and introduced the epicycle of alluviation is not clearly understood. Change in stream-habit, from aggradation to degradation, introducing the terrace epicycle, is best explained also on the hypothesis of climatic fluctuation. Terracing appears to be universal over the Colorado Plateau and adjoining regions at the present time, and an uplift sufficient to produce the results accomplished in the last thirty years would need to have been almost continental in extent and to have been abnormally rapid. The rainfall records at Fort Defiance and at Fort Wingate (Arizona) show no significant cycle either wet or dry, for the years 1880 to 1885,

[8] U. S. Geol. Surv., Water Sup. Pap. No. 380, p. 100, 1916.

the period during which the vigorous down-cutting became dominant, but the rainfall in southern California for 1883-84 was the heaviest ever recorded. Measures of fluctuation in mean annual rainfall have, however, little significance in this region. Erosion results from sudden, violent showers, followed by unobstructed run-off, and, if suitably distributed, in time an annual rainfall of one-half the normal amount may be more effective in denuding the land than a precipitation of twice the normal. Under the present conditions terraces are produced by floods, the streams aggrading during periods of low-water and degrading when the volume is increased — a statement, however, which implies nothing as regards cyclical conditions of aridity and humidity. It is important to note in this connection that the balance between aggradation and degradation is nicely adjusted in an arid region where the stream gradients are steep, and that accordingly small changes in the amount of rainfall, its distribution, or the character of the storms and changes in the amount and nature of the flora result in significant modification of stream-habit. Even the effect of sheep-grazing is recorded in the run-off, and its influence combined with deforestation has been considered by many investigators as the sole cause of the recent terracing in the Plateau Province.

"For the Navajo Country these human factors exert a strong influence, but are not entirely responsible for the disastrous erosion of recent years. The region has not been deforested; the present cover of vegetation affects the run-off but slightly, and the parts of the region not utilized for grazing present the same topographic features as areas usually over-run by Indian herds."

The factors mentioned by Gregory no doubt aid in building up or degrading the fluviatile valley floors; but it seems to the writer that really the main agent in causing the aggrading of the valley floors was man.

The Hopis (and occasionally the Navajos) of to-day build dams and ditches to direct the sporadic flood-waters of the respective washes and also to prevent canyon cutting; also a series of check-dams are often built along moderate slopes and along small washes to retard the run-off and to impound water for stock and household use. Occasionally the valley sides are terraced to prevent arroya cutting. The dams, which are usually about five feet in height, are composed of earth and consequently have to be made