ART. XXXIV.—*Remarks on the Geological Formations along the Eastern margins of the Rocky Mountains*,* by F. V. HAYDEN.

ON several former occasions I have described the different geological periods represented by the rocks uplifted along the margins of the Rocky Mountains and especially along the eastern slope. Examinations over a great extent of country in considerable detail, from latitude 49° south nearly to the Arkansas river, have shown me that quite marked lithological and paleontological changes occur in them all as we proceed from the north, southward. It is the purpose of this article to note this fact somewhat more in detail than hitherto. Beginning with the nucleus of the Rocky mountains at any point along the eastern range, we find it composed of massive granite rocks mostly red feldspathic, but not unfrequently gray or other shades of color; then a series of metamorphic rocks (as they are usually called, though no doubt all the granites should be included with them), syenites, diorites, clay, mica and hornblende slates, and igneous rocks of various kinds here and there.

Proceeding outward we find the Silurian period represented by the Potsdam sandstone, Devonian wanting, then Carboniferous, Red beds (Triassic?), Jurassic, Cretaceous and Tertiary, all connected together in the regular order of sequence, and all but the most recent Tertiary in strict conformity. The Tertiary deposits do not exhibit any marked change either in their mineral or fossil contents from the northern portion of our domain to the Arkansas, but the Cretaceous beds present several quite marked changes. Nos.† 5 and 4 maintain their peculiar characters as shown on the Upper Missouri, wherever they are exposed all along the eastern slope, except that they contain comparatively few fossils, yet a few characteristic species are found wherever these beds are seen, which identify them. On the Missouri river, No. 3 attains a great thickness, 400 to 600 feet, presenting massive escarpments of yellow chalk, and it can be traced all the way across the prairie country lying between 98° and 100° longitude. At Forts Hayes and Wallace on the U. P. R. W. E. D., there are massive beds of this chalk which is sawed into building blocks with a common saw, and in many instances it is nearly as white as our chalk of commerce and

* This article refers only to the eastern ranges of the Rocky Mountains, extending south to the Arkansas. The same remarks may or may not apply to other portions.

† The different divisions of the Cretaceous period, as shown on the Missouri river, have received geographical names, as Fort Benton group, &c., but I use the old divisions by figures for brevity.

might be used for the same purposes. The two characteristic species of fossils of this division are found everywhere, *Ostrea congesta* and *Inoceramus problematicus*. All along the slope of the mountains No. 3 still retains its chalky nature but becomes quite shaly, none of the layers ever becoming more than one or two inches in thickness. This is the case at the sources of the Missouri along the Big Horn and Wind river mountains also, from the South Pass to Pike's Peak, and on the western slope wherever this bed is exposed. Near Denver, at Marshall's coal mine, No. 3 has been changed by heat into a grayish compact limestone, quite hard and brittle in its fracture, which makes an excellent flux in smelting ores. But this change is local, for 16 miles north of this point it presents the same laminated character. It seems that No. 3 loses its massive chalky character, by which it first attracted attention on the Missouri river, in its westward extension, so that along the margins of the mountains except in one locality it cannot prove of any economical value, while between 98° and 100° longitude it becomes very useful not only for lime but also for building purposes. No. 2, like Nos. 4 and 5, retains its dark plastic clay character everywhere that it has been observed, but like the others it is not nearly as well developed in Colorado as on the Upper Missouri. Near Fort Benton it attains a thickness of 200 to 400 feet, while in Colorado it is not more than 50 to 150 feet. Between longitude 96° and 99°, No. 1 retains its deep rust-red sandy characters with dicotyledonous leaves, from the Missouri river to the Arkansas, but nowhere along the margins of the mountains from lat. 49° to Pike's Peak have I ever seen any well defined paleontological proof of its existence. Near Fort Benton are a series of Cretaceous beds containing some seams of impure lignite, and numerous species of fossils, not one of which is identical with those so abundant in Nos. 4 and 5 lower down on the Missouri. These beds have been placed provisionally in the general section as a portion of No. 1, but the region about Fort Benton needs a more careful examination before any positive conclusions can be arrived at. Around the Black Hills is a bed of massive siliceous rocks, some layers forming a pudding stone which in some localities takes the name of fortification rocks. These hold a position between No. 2 Cretaceous and the Jurassic marls. The same are seen along the margin of the Big Horn mountains, in which I observed a bed of impure lignite, an abundance of silicified wood, and some uncharacteristic Saurian bones. From the Wind River mountains to Pike's Peak, these same siliceous and pebble cemented rocks occur holding the same geological position, forming, as it were, beds of transition between the Cretaceous and

the Jurassic periods. I have carefully examined these rocks for hundreds of miles and have never yet detected any organic remains, animal or vegetable, in them.

The Jurassic beds, as revealed along the mountains, possess peculiar and marked lithological characters, so that having identified them by the fossils in one locality we can trace them over great areas. They were first shown to exist in the west in the form of a zone engirdling the Black Hills. They here attain a thickness from 200 to 300 feet at least, and from the beds in this locality alone have fossils enough been collected of such unmistakable Jurassic types as to prove their existence beyond a doubt. But these beds have also been shown, since they were first made known in the Black Hills, to be exposed along the margins of the Big Horn and Wind River mountains near Red Buttes, on North Platte and in numerous localities in the Laramie Plains, and westward to Fort Bridger; so numerous are the species now known from the west and so close are the affinities of most of them to well known Jurassic types that it is not necessary for me in this place to detail the evidence in support of that statement.

It is sufficient to remark, that the Jurassic system is quite plainly represented along the margins of the different ranges of mountains north of lat. 42° , but proceeding southward from Deer creek on the North Platte, the Jurassic beds diminish in force until near Cache la Poudre it becomes doubtful whether they are represented at all. At this point there is a thin bed, perhaps 20 to 50 feet in thickness, of greenish gray arenaceous marl overlying the red beds which seem to occupy the place of the Jurassic. This seems to thin out more and more as we proceed southward toward the Arkansas. From Deer creek 100 miles north of Fort Laramie to Denver, a distance of 400 miles, I have searched in vain for any organic remains in the rocks which appear to represent the Jurassic period of the Black Hills, Big Horn and Wind River mountains. In the Red beds or supposed Triassic, no organic remains have been found north of the Arkansas and they do not differ much lithologically in their southward extension except that they seem to be much thicker and more gypsiferous northward. In the far north the Carboniferous rocks are in many localities 500 to 1500 feet in thickness, and even as far south as the Red Buttes the massive beds of limestone with true Carboniferous fossils are exposed 500 to 1000 feet thick and are quite distinct from the red or variegated beds. But as we proceed southward from this point the Carboniferous limestones seem to lose their usual lithological characters and the red beds prevail. At the head of Pole creek on the eastern margin and in the Laramie Plains west, the Carbonifer-

ous rocks are mostly of a red arenaceous character, with a few layers 2 to 10 feet in thickness of whitish or yellowish limestone. From these limestones I collected *Productus Prattenianus*, *Athyris subtilita* and other well known Carboniferous forms. Above these red beds which contain intercalated layers of limestone is a considerable thickness of purely red arenaceous beds, but in studying all these rocks with some care from Pole creek nearly to Pike's Peak, I could not separate the red beds from the Carboniferous by any break in continuity, and I was rather inclined to the opinion that inasmuch as a large portion of the gypsiferous or variegated beds could be shown to be Carboniferous, they might possibly all be included in that period. The Potsdam sandstone, the only portion of the Silurian era ever detected along the eastern slope of the Rocky mountains north of the Arkansas, seems to fade out entirely south of the Red Buttes on the North Platte. It is well defined around the Black Hills, Big Horn and Wind River mountains. Near the Red Buttes there is a bed of siliceous pudding stone resting on the metamorphic rocks which may be the Potsdam in its southern extension, but south of Fort Laramie to Pike's Peak, it is somewhat doubtful whether any trace of it exists. If it occurs at all it is a very thin layer, for the most part concealed. So far as I could determine, the Carboniferous rocks rest directly (though not conforming) upon the metamorphic rocks. There is also some change in the nuclei of the mountain ranges southward. At the north the feldspathic and the gray granites prevail but southward the syenites and igneous rocks form the central portions of the mountains almost entirely. It is rare to see true granite.

The above remarks, founded on observations that have been made over a very great extent of country through a period of many years, lead me to the following conclusions. 1st. That all the formations of the west undergo more or less change both in their mineral and fossil contents in their extension toward the west and south. They all seem to reach their culmination not far from the central portion of the great area drained by the Missouri, and lose to a great extent their distinctive characters beyond its limits.

2nd. The Potsdam sandstone and the Jurassic beds present more remarkable changes than any of the others. While north both these formations are well marked, both lithologically and paleontologically; in their southward extension they gradually fade out so that south of Fort Laramie to Pike's Peak, it becomes a matter of doubt whether they exist at all. The inference therefore is that these groups of rocks are not well defined, if they occur at all south of the Arkansas. In support of this statement is the fact that although this southern region

has been traversed in every direction by multitudes of explorers for thirty years past, among whom have been geologists of high reputation, yet south of lat. 40° not a single animal fossil has ever been detected with Jurassic affinities, and it is quite doubtful whether any have been found with Triassic or Permian relations,* even the few plants that have been found are doubtful in their affinities and are regarded as probably Cretaceous or Permian. I have made these remarks from the fact that all the observations that have been made by explorers in the west during the past will, ere many years, be put to the rigid test of a most careful scrutiny, and an error by whomsoever made, though sustained by the highest authority in the land, will fall to the ground before the light of true science as the dead bark from a tree. The ease with which the Rocky mountain region can soon be reached in a few years, when our great national highways are completed to the Pacific, will induce the best geologists in this country and in Europe to visit them, and the many intricate problems of Rocky mountain geology must be solved.

The great School of Mines which will no doubt be soon established in the heart of the mining districts of the Rocky mountains, must gather around it able men who will either sustain or reject the observations of other investigators who have examined the country under less favorable auspices.