

ART. XIII.—*The Little Cottonwood Granite Body of the Wasatch Mountains*; by S. F. EMMONS.

THE Wasatch Range, from a geological standpoint, is the most important of the many more or less parallel mountain uplifts that go to make up the Cordilleran Mountain System in its widest part—that is, between the latitudes of 39° and 41° N. It has, from the earliest geological time of which we have any record, formed the dividing line between the geology of the west or Pacific slope and of the eastern Rocky Mountains, there being an essential difference on either side of this line, not only in the lithological constitution of the respective geological formations but in their faunal characteristics.

From a Tectonic point of view it is equally important, presenting as it does examples of most of the varied phenomena involved in mountain building, the latest phase having been a great meridional fault which has cleft it in twain, so that its western half is now buried beneath the floor of the Great Salt Lake Valley; it is thus well worthy of the characterization given it by the elder Dana, as “the grandest exhibition of facts pertaining to an individual case of mountain building in geological literature.”*

It was in the summer of 1869 that the geologists of the 40th Parallel undertook the geological examination of this range. The two previous seasons had been devoted to geological mapping† of the Desert Ranges of Nevada and western Utah. In these isolated ridges, standing like islands in a great ocean of recently deposited sediments, the rocks were found to be mainly eruptives and members of a great Paleozoic series whose extent, position, and faunal characteristics in the vast region west of the Mississippi Valley were as yet completely unknown, and the facts gathered so far had afforded no clue whatever as to the extent or order of superposition of the different members of this portion of the sedimentary column.

As our weary march across the desert in the season of 1869 had finally, in the month of November, led us along the western foot of this magnificent range through the smiling

* This Journal (3), xlv, 181.

† It is perhaps questionable whether the word “mapping” is the correct term in this place, for at the time no maps of the region were extant and topographer and geologist did their field work side by side. It was not until 1875 that the paleontologists had furnished their final determinations of the age of the various groups of fossils collected and the topographers had completed their maps so that the geological outlines might be laid down upon them.

fields and orchards of the Mormon farmers, we looked with delight at the deep clefts of the many canyons that scored its flanks, foreseeing that here at last might be found a key to the problem that so long had troubled us, in the actual superposition of the complete Paleozoic series.

As originally planned, the season of 1869 was intended to complete the field work of the 40th Parallel Survey. There remained of the Desert Region all the ranges from the Wasatch westward to the western edge of the Great Desert, and east of the Wasatch the western end of the Uinta Range and a portion of the Tertiary Basin of Green River were included within our field of work, an extent of country 125 miles long in an east and west direction and with a normal width of 102 miles north and south or 12,750 square miles. To cover this area required the utmost diligence and careful allotment of the time from May to November, in which alone field work was possible at that latitude and elevation. Three weeks were all that could be allotted for the topographic and geological reconnaissance of the whole Wasatch range south of the latitude of Salt Lake City, which fell to the lot of my party. It can readily be conceived that under such relations of time to area many phenomena would necessarily be but imperfectly observed. As regards the completeness of the geological column, expectations were more than realized. It was found that not only was the entire Paleozoic section completely developed but representatives of two series of pre-Cambrian formations and of a remarkably full suite of Mesozoic and Tertiary formations were exposed in this range. In the field, therefore, attention was mainly devoted to the working out of the columnar section, and it was not until many years afterwards, when, by the completion of the topographic maps, it was made possible to represent their relations graphically, that the true import of some of the great structural problems involved could be fully appreciated.

I have gone somewhat at length into these preliminary observations because the purpose of this paper being to acknowledge that an important mistake was made in the course of the work, it seems no more than justice to those that carried it on—more particularly to our deceased chief, Clarence King, to whose genius and energy was due the conception and carrying out of this great work and who personally drew all its most important conclusions—that geologists of the present day should have a realizing sense of the conditions under which it was carried on. During the nearly thirty years that have elapsed since its conception, I have had opportunities of verifying the work in many parts of the field in the light of the more complete knowledge of later times, and it has always

been a matter of wonder to me that so few mistakes were made.

The problem which had the most important bearing upon the earlier history of the Wasatch Range proved to be that with regard to the age of the Little Cottonwood granite. This is a huge, homogeneous body, somewhat in the shape of a half dome, which forms the mass of Lone Peak and the lower two-thirds of Twin Peak, and is well exposed in the deep glacial trough of Little Cottonwood Canyon that runs in a nearly straight west line between the two. Around this mass and in general dipping away from it on the north, east, and south wrap the series of Paleozoic sediments, which curve in strike from northwest on the north through north-south to northeast on the south. The lowest member of this series consists of 12,000 feet of Cambrian beds, mainly quartzites, which alone come in contact with the Cottonwood granite body. On the west face of the granite rest a series of westerly dipping crystalline schists of assumed Archean age. These beds are unconformably overlaid by the Cambrian beds, which differ from them nearly 90° both in strike and dip. That the granite was intruded into and hence later than these Archean beds is readily evident, the contacts lying along the valley slope of the range, where they can easily be seen. The contacts of the granite with the Cambrian beds, on the other hand, are less easy of access, being mostly high up on the steep mountain slopes and covered by brush and talus, so that in the time allotted for exploring this region few were actually observed. Two alternative solutions of the problem presented themselves, which are indicated by Mr. King* as follows:

“It is very evident that the granite is either an intrusive mass or else an original boss on which the sedimentary material was deposited.” The close lithological resemblance of this granite to the Jurassic granites of the Sierra Nevada had at first suggested its later intrusion, but after careful weighing of all the evidence it was concluded that the preponderance was in favor of its pre-Cambrian origin. The Clayton Peak mass farther eastward, at the head of Big Cottonwood Canyon, though separated at the surface by several thousand feet of easterly dipping quartzites and limestones, and of somewhat different structure, was assumed to be part of the same boss. This assumption necessitated in Mr. King’s reconstruction of the Archean surface, on which the Paleozoic sediments were deposited, the existence in this part of the original range of a steep cliff of about 30,000 feet elevation.

While there is abundant evidence in other parts of the 40th Parallel region to support Mr. King’s statement that the pre-

* 40th Parallel Reports, vol. i, “Systematic Geology,” p. 48.

Cambrian topography must have been of far bolder type than that of the present day, the existence of this 30,000 foot cliff has been regarded by geologists with some incredulity.

As the result of a brief personal visit to the region, Professor (now Sir) Archibald Geikie published a criticism* of Mr. King's views, based largely upon improbability of the existence of a cliff of such enormous dimensions, and concludes that the intrusion must be of post-Carboniferous age. Later in his text-book of geology he quotes this occurrence as "shown to be of post-Carboniferous age."†

A reply to Professor Geikie's criticism, on the part of Mr. King and myself, has awaited the opportunity of making a further study of the region which should be conducted with sufficiently greater thoroughness than either of the previous examinations to settle the question once for all. In consequence, however, of the extreme ruggedness of the region and the difficulty of access by most of the contact lines, lying as they do along the edges of precipitous mountain summits, such an examination would require several weeks' work with a camping party and the opportunity of making it has hitherto not presented itself. In Chapter VI of my report on the "Geology of Leadville," however, in discussing the extent of the absorbability of sedimentary rocks by eruptive masses, I took occasion to refer to one of the arguments that had influenced us in arriving at the conclusion that the Little Cottonwood granite was pre-Cambrian. This was, briefly, that the other assumption, namely, that it was later than the Cambrian quartzites that rested upon it, involved the absorption of some 500 cubic miles of these quartzites by the intrusive magma which ought to have resulted in making the magma unusually acid, whereas in point of fact, the Cottonwood granite has only 71.78 per cent of silica, which is but normal and not a specially acid type. I also referred to the fact that no included fragments of Cambrian quartzites had thus far been found in granite, although along the Archean contact, near the mouth of the canyon, such included fragments are of frequent occurrence. On the other hand, I did not mention the fact that occasional pebbles of granite had been found in the quartzite, for the reason that we had not yet observed marginal zones of basal conglomerates, such as Professor Geikie very justly observed ought to be found at the base of such slopes of land.

Van Hise‡ examined the canyon in 1889 and found granite pebbles in the Cambrian quartzite which he, however, regarded as lithologically unlike the Cottonwood granite. He considered the Cottonwood and Clayton Peak granites as identical

* This Journal (3) xi, p. 363.

† Edition of 1882, p. 646.

‡ U. S. Geological Survey, Bull. 86, p. 294, 297.

in character and found the limestones in contact with the latter exceedingly metamorphosed. He does not, however, appear to have found any evidence of intrusive nature at the actual contact of the Cottonwood granite body with the Cambrian quartzite. In reviewing the published evidence on the subject, he is more inclined to favor the view favored by Geikie than that of the 40th Parallel geologists, though he admits that he does not regard the objections to the latter view of so insuperable a nature as did Geikie.

In the past few seasons several pieces of Survey work have been carried on under my supervision in this portion of Utah, and I have taken advantage of the opportunity of having younger legs than my own at my disposal to have the more inaccessible portions of the granite contact along Littlewood Canyon more closely investigated.

Already in the summer of 1900, at the close of his field work in Bingham Canyon, Mr. J. M. Boutwell at my request examined the contact of granite and quartzite on the south face of the Twin Peak ridge, a few miles below Alta, and found several apophyses of granite cutting into the quartzite beds above the contact. Mr. Boutwell courteously refrained from publishing the results of his examination until I should have an opportunity of personally examining the contact. This occurred during the past summer, when Mr. Boutwell's party was making a survey of the Park City district, within a few days' ride of this locality, and the object of this paper is to state the result of this examination.

That the Cottonwood granite body is intrusive in the Cambrian quartzite is proved by the existence of apophyses of the former running across the bedding of the latter for some distance and in one observed instance spreading out again between the beds in a considerable body.

On the other hand, no metamorphism of the contact could be distinguished megascopically, and in the canyon bottom the upper surface of the granite is smooth and even, conforming with the bedding planes of quartzite, while small, rounded pebbles of a granitoid rock are found in the bed of quartzite immediately above the contact. At the mouth of the canyon the western contact of the granite body with the Archean schists is much more distinctly intrusive, being very ragged and uneven, while fragments of the former, both large and small, are included within the granite.

For a distance of over a mile above the eastern contact of the granite, quartzites and limestones, dipping steeply eastward, occupy the bed and sweep up on either wall of the canyon, thus separating the Cottonwood from the Clayton Peak eruptive body by an estimated thickness of two to three thousand feet of sedimentary beds.

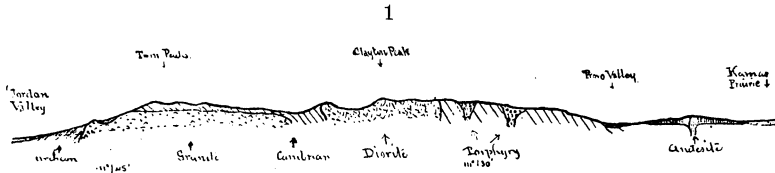
The outcrop of the Clayton Peak body occupies the divide between the heads of Little and Big Cottonwood canyons, the basin at the head of the latter canyon, and the mass of Clayton Peak which forms its eastern rim; it also extends for some distance east of the latter peak in the plateau-like basin at the head of Little Snake River, where its outcrops are obscured by surface accumulation.

In my original visit to the head of Big Cottonwood Canyon, in 1869, I collected a specimen of crystalline garnet rock which presented something of a schistose structure and was thought to belong to the Archean complex. At that time the results of the studies of contact metamorphism by Doelter and others in the Predazzo-Thal and other classic localities in Europe had not been published, and even to Prof. Zirkel, who examined the specimen microscopically, the suggestion did not present itself that this was probably a phase of contact alteration of limestone. At the present day, however, when the original dense forest-covering has been cleared away and prospectors have sunk holes wherever the contact of limestone and granite is exposed, these contacts are readily observed and show conclusive evidence of the later intrusion of the granite into limestone in the abundant development of contact minerals, such as vesuvianite, garnet, etc., and of contact deposits of ores of the metals, in which the association of magnetite with pyrite, chalcopyrite, galena, etc., is most common. Marmorization of the limestone is abundant in the region and by no means confined to the contact belt, but, as Mr. King observes, spreads out over large areas in the limestone beds that have no definite relation to any known outcrop of eruptive rock.

The prevailing rock of the Clayton Peak rock is a granular diorite of the same general mineralogical composition as the Cottonwood granite, but of finer grain and apparently carrying less quartz and a greater proportion of basic silicates. The western portion of this body on the divide between Big and Little Cottonwood canyons, however, is of somewhat coarser grain and resembles the granodiorites of the Sierra Nevada. A small body exposed in Big Cottonwood Canyon, about two miles below the bend and in the same general geological horizon as the Clayton Peak mass, but some four miles north of the outcrop of the Cottonwood granite, is of the fine-grained dioritic type characteristic of the Clayton Peak mass.

Each of the diorite body of the Clayton Peak, the eastern spurs of the Wasatch Mountains, are made up of Paleozoic beds cut through quite irregularly by stocks and dikes of eruptive rocks of distinctly porphyritic structure, though of the

same general mineralogical composition as the diorite. These general relations are shown in the accompanying profile of the range on a general east and west line running through Twin Peak, the head of Little Cottonwood Canyon, and Clayton Peak.



A broad depression between the eastern foothills of the Wasatch Mountains and the western flanks of the Uinta Mountains is largely covered by andesitic lavas, overlying bedded tuffs of an undoubted extrusive nature, which are of Tertiary (probably post-Eocene) age. These rocks have a striking resemblance in their mineralogical composition to the diorites and porphyries of the Clayton Peak mass.

While, therefore, it must be admitted that the geological history of the region, as traced by the geologists of the 40th Parallel, is not entirely correct, it is yet too early to state exactly how far and in what way it should be modified. This must await a thorough resurvey of the region based on large scale maps, a work which has already been inaugurated by the geologists of the Survey; inasmuch, however, as it will probably be several years before this work will be sufficiently far advanced to afford final solutions of some of the most critical problems, it may be permitted to state what these problems are and to present some alternative hypothesis as to their probable solution. It is certainly a most striking fact that these several eruptive bodies, which apparently are of sufficiently similar mineralogical and chemical composition to have originated in the same general magma, occur along the line running a little north of east, which, if extended westward, would pass through the mining district of Bingham Canyon where occur the most important intrusions of porphyritic eruptive rocks in the Oquirrh Mountains, and where there have also been outpourings of later extrusives of consanguineous character along the flanks of the range. The same line, extended still farther westward to the parallel range of the Aquia Mountains, passes through a small body of extrusive, andesitic lavas and tuffs on the east flanks of that range, which, so far as known, is the only point where eruptive rocks are found in it. Attention was called to this fact in my original description of the geology of this region,* and also to the fact that along this line in the

* 40th Parallel Report, vol. ii, Descriptive Geology, p. 459.

Oquirrh and Wasatch Mountains there has been the greatest concentration of ore deposits. This generalization holds good at the present day, but modern developments show that there is an evident genetic connection with the older eruptives, while none is apparent with the extrusive flows.

The further statement in my original report,* that in the Wasatch range the mineral deposits are mostly concentrated within a radius of 6 or 7 miles around Clayton Peak, also holds good in the light of present developments, which, moreover, point to a more intimate genetic relation of ore deposition to the Clayton Peak than to the Cottonwood body, for as far as known no ore deposits have been found on the contact of the latter with the surrounding rocks, whereas they are most common around the Clayton Peak mass. It must be noted, however, that these deposits occur for the most part in calcareous rocks, and no calcareous rocks are known to occur in contact with the Cottonwood granite. It may be assumed that the Cottonwood granite, if regarded as a distinct body, did not reach a higher horizon than a thousand feet or more below the top of the Cambrian quartzite. That the Cottonwood and Clayton Peak granite beds were part of the same mass and hence of contemporaneous origin, was a plausible assumption as made by the 40th Parallel geologists but one which has not yet been supported by the finding of any connection between the two on the surface. In the absence of such connection a possible alternative hypothesis is that there have been successive eruptions in this region from the same general magma, each of which reached a higher geological horizon than the preceding one. On this hypothesis it may be assumed that the Cottonwood batholith was intruded while the Cambrian beds were still resting undisturbed upon the upturned edges of the Archean, and that it did not reach the top of the Cambrian; that this eruption was followed later by the mountain-building movement which threw the Paleozoic beds into anticlinal and synclinal folds, and that after they were thus upturned, the Clayton Peak mass intruded into the Carboniferous limestone and produced the well recognized contact phenomena now seen. The stocks or dikes of porphyry in the somewhat higher geological horizons to the eastward might have been contemporaneous or slightly later eruptions from the same general magma, and have owed their less completely crystalline structure to the differing conditions under which they consolidated. The abundant mineralization in the region has evidently been in part a direct and in part an indirect result of this phase of activity.

As regards the extrusive flows in the depression between the Wasatch and Uinta Mountains, they rest on a surface from

* *Ibid.*, p. 364.

which not only Mesozoic but a great thickness of Eocene Tertiary beds must have been denuded, hence a long period must have elapsed between the older eruptions and this one, which, by analogy with the regions to the westward, may be assumed to have occurred during the Miocene period.

It has been assumed as a result of the 40th Parallel work—an assumption that has not yet been seriously modified by later investigations—that while there was in the Cordilleran region toward the close of the Carboniferous a general elevation of the Great Basin region accompanied by greater or less erosion, the main mountain-building movement occurred at the close of the Jurassic. In the Wasatch some evidence of a transgression at this period was found by the 40th Parallel geologists, but it was not insisted on in their reports because without a reëxamination of the field it could not be considered absolutely conclusive. It would now appear probable that the eruption of the Clayton Peak mass must have been contemporaneous with or closely followed this Jurassic movement. If future investigations prove that the Cottonwood body is of the same age as the Clayton Peak mass, there will be found exposed here in unusual detail the contact phenomena of an enormous granitic batholith, extending in horizon from the Archean across a vertical column of 25 to 30,000 feet of sedimentary beds of varying composition, and an opportunity will be afforded to study what influence, if any, has been exerted on the intrusive magma by the rocks through which it passed and which, presumably, must have been absorbed by it.

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