Prof. H. Lakes gave a sketch of his experiences in finding the gigantic Dinosaurs in the Upper Jurassic strata at Morrison, Colorado, and in Wyoming Ter., which have since been described by Prof. O. C. Marsh.

MEETING OF JUNE 4TH, 1883.

Mr. van Diest announced that he hoped to be able to present to the Society at an early day the results of an examination of the building stones submitted to the State Capitol Commission; an examination conducted by a special board of engineers appointed by the Governor, of which Mr. van Diest was a member.

He then gave a description of the primitive methods employed by the Chinese in smelting the tin ores of the island of Banka, and also of the improvements and alterations in these methods introduced by himself. He further described the methods used in assying the tin ores.

Mr. Pearce gave a sketch of the tin occurrences of Cornwall, Eng., showing the geographical distribution and chief facts as to the relations of the ore veins to the country rock. He promised a more extended description at some future meeting.

MEETING OF OCTOBER 1ST, 1883.

Extinct Glaciers of the San Juan Mountains, Colorado, BY R. C. HILLS.

That portion of the Rocky Mountain range which, for the purpose of this paper, will be considered as the San Juan Mountains, includes the whole of the elevated region embraced in the counties of Hinsdale, San Juan, Ouray, San Miguel, Dolores, Rio Grande and La Plata.

The drainage east of the Continental Divide constitutes the source of the main branch of the Rio Grande, while that to the westward includes the principal tributaries of the San Juan and the southern tributaries of the Grand and Gunnison. The volume of water conveyed into the Rio Grande is small compared with that which, flowing westward, fur-

nishes more than half the total volume of the Colorado River. In fact, the volume of the Rio Grande from this source only does not exceed that of either the Dolores or Animas streams which are simply tributaries of the Grand and San Juan.

The extent of glacial action in the past seems to have been in a great measure proportional to the magnitude of the existing river systems, and it is found that not only was there a greater thickness of ice on the western slope, but the area of glaciation was many times more extensive. Evidence of the former existence of glaciers in the Rio Grande drainage area is most decided in the region lying west of Wagon Wheel Gap. For a distance of twenty-eight miles above the Gap, the river bottom, which is seldom less than half a mile wide, is a continuous deposit of drift. Above this for some distance the fall of the river is considerably increased, and the surface of the eruptive rock here forming the river bed is, where exposed, usually smooth and rounded. There are no accumulations of drift, or if such ever existed they have since been carried away. Succeeding this is a swampy bottom about four miles long, extending nearly up to Lost Trail Station, and terminated at its lower extremity by a moraine. It is separated from a third and smaller valley, lying between Lost Trail and Timber Hill, by a few well rounded hills cut by the river. Timber Hill is equidistant about seven miles from the semicircular ridge dividing the Atlantic from the Pacific drainage and enclosing a section of country that, with the exception of the higher peaks, appears to have been thoroughly glaciated.

Of the lateral ice streams flowing into the Rio Grande Valley, the greatest was probably that of Clear Creek. It originated in the country lying above Clear Creek Falls, which is at the present time mostly below an elevation of 10,500 feet. A short distance down the valley from the Falls the ice stream was divided, one portion entering the Rio Grande Valley at Antelope Park and the other portion at Antelope Springs, three miles to the eastward. The latter branch formed the depression known as Santa Maria Lake; and, during its retreat, the huge terminal moraine one mile above the springs.

From the Continental Divide at the head of the Rio Grande to Wagon Wheel Gap the distance is about fifty-two miles. Below the Gap there is evidence that glaciers

flowed in from the Divide to the southward, but it does not appear that the main glacier extended east of the Gap. Judging from the glaciation on the hills flanking the valley, the main glacial stream did not exceed five hundred feet in thickness, and its extraordinary extension eastwards must have been due to additions from lateral sources. In comparison with the country west of the Divide, the glacial features of the Rio Grande valley are of secondary interest, and it is to the Pacific slope of the mountains more particularly that I wish to direct attention. That a long continued period of extensive glaciation existed there is shown by the frequent occurrence of drift along thc western margin of the undulating plateau region lying near the base of the main range, and by the scratched and fluted surface of the crystalline schists and such eruptive rocks as have resisted disintegrating action in and around the main range itself. In addition, morainal deposits are a conspicuous feature in the flat, swampy bottoms, known as parks, of frequent occurrence along the principal streams. It does not appear that the glaciers were always confined to the existing valleys, but that at some remote period the entire western slope of the mountains, except probably the highcr peaks, was covered with an unbroken sheet of ice. The extension of this sheet westward was doubtless aided to a considerable degree by additions of glacial material from three more or less isolated groups of mouutains, viz: the Tongue Mesa, Mount Wilson and La Plata groups.

The western limit of the ice sheet at the period of greatest extension is not always well marked, yet sufficiently so at intervals to admit of its being defined with some approach to accuracy. From the Rio Navajo northward to the Mancos Valley the ice plowed down through the Fox Hills sandstone into the Colorado shales, sometimes to the level of the Dakota, leaving an irregular line of escarpments and low hills facing the Needle and La Plata Mountains. These escarpments are especially noticeable between the Animas sud Mancos Rivers, where the depth of erosion from this cause alone is from 250 to 500 feet. Similar escarpments occur fronting the Mount Wilson and Lone Cone groups of mountains. In the Animas River region bowlders of quite large size, usually granite, are distributed over the country five miles west of the town of Durango and nearly sixty miles from the source of the Animas River. No rocks are ex-

posed in the vicinity older than the Colorado Cretaceous, and the nearest exposure of granite is at Elbert, eighteen miles up the river.

In the Rio San Miguel region the ice moved westward with the general course of the San Miguel River and crossed diagonally the course of the south branch of that stream. To what distance it extended I am unable to say, but I have observed erratic bowlders of eruptive rock on the mesas flanking San Miguel, thirty-five miles from the source of the river.

In the country immediately south of the Uncompahgre River it does not appear that the ice extended west of the mouth of Dallas Creek. In the region between the Uncompahgre and Cimarron the extension was much greater. For several miles west of Tongue Mesa the country is covered with coarse bowlder drift, composed largely of eruptive rocks derived from the Tongue Mesa Mountains. The western limit of this area is marked by a long ridge of Archaean rocks running diagonally from the Cimarron southwesterly to the Uncompahgre Valley, and known as the Vernal Mesa. Consequently the greatest extension of drift is toward the latter, where erratic bowlders may be observed twelve miles west of the extremity of the Tongue Mesa and within a short distance of Montrose. Similar features are observable in the section of country lying between the Cimarron and the mouth of Indian Creek on the Lake Fork of the Gunnison.

As the ice sheet retreated it became divided and finally separated into distinct glaciers corresponding to the drincipal valleys. Of these the Animas glacier was probably the largest. It formed the beautiful and fertile Animas Park in La Plata County, and Baker's Park in San Juan County. It was augmented by large additions of glacial material from the Needle and Cascade Mountains, and a short distance above Elbert was probably at one time nearly three miles wide. Between Elbert and Silverton the rounded surfaces of the crystalline schists exhibit glacial scratches 1200 to 1500 feet above the old glacier bed. Two parallel terminal moraines cross the lower end of Animas Park at Animas City. There is a moraine at the lower, and another at the upper end of Baker's Park.

Next in importance was probably the Hinsdale glacier, occupying the upper valley of the Lake Fork of the Gunni-

son. It formed the basin of Lake San Cristobal, and, as shown by the drift covering the hills northeast of Lake City, was at one time nearly a mile wide. Lake City is about twenty four miles from the source of the river and about fifteen miles from the nearest point on the Continental Divide. Owing to kaolinization and other causes the rocks bordering the lower portion of the district have not retained the characteristic glacial scratches, and the only indication of the probable thickness of the Hinsdale glacier is the presence of drift material, which is abundant 800 feet above the level of Lake San Cristobal.

The Uncompahgre glacier was eighteen miles long, extending to the foot of Uncompahgre Park and to within a short distance of the mouth of Dallas Creek. It deposited the huge moraine, over 150 feet high, which crosses the lower end of the Park. Below the town of Ouray only friable sandstones and shales are exposed and glacial striae are absent. Above Ouray the quartzites and schists are scratched and polished 800 feet or more above the bed of the Uncompahgre river.

On the La Plata the local glacier was about fifteen miles long, and in places three-fourths of a mile wide, extending more than six miles below Parrott City. A glacier of about equal dimensions occupied the valley of the Mancos. The drift forming the substratum of the Mancos Valley is largely mixed with clay, probably owing to the enormous amount of shale eroded by the glacier.

On the North Fork of the San Miguel was a glacier eight miles long and about 200 feet thick towards its Western extremity. It extended to the lower end of what is known as Gold Run, a swamp valley terminating in a moraine about thirty feet high. The glacier of the South Fork of the San Miguel was about fifteen miles long, and debouched into the main valley a short distance below the lower end of Gold Run It was augmented by the Lake Fork glacier, the latter forming the depression occupied by Trout Lake. The only indication of the probable thickness of the South Fork glacier is the occasional occurrence of fluted surfaces on the precipitous granite exposures below the town of Ophir, which can be observed 400 feet above the smooth granite bed of the old glacier and on both sides of the river.

On the San Juan, Navajo, Los Pinos, Piedra, Florida

and Dolores, all of which streams I have visited, local glaciers of greater or less extent once existed; but those I have described were probably the most important, at least their history is the best preserved.

During the period of the extension of the ice sheet the Upper and Middle Cretaceous rocks were eroded from 200 to 500 feet, in some places more, the amount of erosion being greater where shales predominated, as for instance, in the section of country immediately north of Animas City.

That a long period of time elapsed between the retreat of the ice sheet and the final retreat of the local glaciers is shown by the depth of erosion in the South Fork of the San Miguel. As before remarked, the course of this stream is diagonal to the direction of movement of the San Miguel portion of the ice sheet, which was approximately that of the main valley. The South Fork glacier cut down through not less than 800 feet of Cretaceous sandstones and shales, forming a cañon nearly half a mile wide, bordered at intervals by escarpments of sandstone. The erosion of this cañon must have taken place since the retreat of the ice sheet and before the retrograde movement of the local glacier had reached the junction of the South Fork with the main stream. However, the South Fork cañon does not represent the average depth of erosion by local glaciers, but rather the maximum, for in most instances it has not exceeded half this amount.

Since the retreat of the local glaciers to the upper valleys the rivers have excavated chasms, or what are usually termed "box cañons," fifty to one hundred feet deep, according to the velocity of the current and character of the eroded rock. Evidence of this nature is shown in the Uncompahgre cañon near Ouray, in the cañon of the Animas above Elbert, on the Dolores above Rico, and on the Lake Fork of the Gunnison above Lake City. The depth of these chasms gradually decreases toward the heads of the streams, notwithstanding that the fall gradually increases, and around the sources of all the rivers rising in the San Juan Mountains we find localities where the water is flowing but a few feet below the striated rock surface of the old glacier bed.

It is not unusual to find in these mountains limited accumulations of *nèvé* that never entirely disappear. There are two of these at the head of Henson Creek, near the

point where the Animas Forks wagon road crosses the divide, at an elevation of 13,000 feet. They are seldom less than fifty feet thick, from 100 to 300 feet wide, and from 400 to 600 feet in length. I visited the smaller of the two on the 20th of September of the present year and found a stream of water, caused by the melting of a recent fall of snow, running the whole length of its trough-like surface. Scraping away some of the loose snow I discovered that the mass was solid ice into which light was transmitted some distance. It seems moderately certain that the Glacial period of this portion of the Rocky Mountains extended nearly up to the present time, and that the *nevè* accumulations found on the head of Henson Creek and elsewhere are the remnants of the ice envelope which, at a remote period, covered nearly the whole of the habitable portions of Hinsdale, San Juan, Ouray and San Miguel counties, and a large portion of the counties of La Plata, Dolores and Rio Grande, extending over a territory of more than 4500 square miles, or about equal to the area of Arapahoe county.

Regarding the comparative excess of ice on the Pacific slope of the mountains, I think some explanation may be found in the cause producing an excess of water on that slope at the present time. Inspection of one of the official maps of this region shows that the Continental Divide forms a long elliptical curve opening to the eastward, enclosing the country drained by the Rio Grande, and in general conforming to the contour of greatest mean elevation. An examination of the eruptive rocks of different localities indicates that the present curve represents approximately the trend of the Continental Divide at the close of the last period of disturbance, for we find rocks belonging to the more recent overflows dipping from the Continental Divide into the Rio Grande Valley, so that the rocks occurring between Del Norte and Wagon Wheel Gap are contemporaneous with those found near the divide, north, south and west. As a result, nearly four-fifths of the region circumscribed by the contour of 8,000 feet is thrown west of the divide, and this fact sufficiently explains why there is such a limited volume of water flowing to the east as compared with that flowing to the west, which is to be referred to topographical rather than to meteorological conditions. There can be no doubt that the last period of disturbance ante-

dated the period of glaciation, and that therefore the greater accumulation of ice on the western slope was due to substantially the same cause that now determines the greater flow of water in that direction.

[DISCUSSION.]

Mr. McCree gave a number of personal observations in the same district, confirmatory of the statements of Mr. Hills.

Mr. Emmons thought that meterological conditions would naturally cause a greater rainfall and thus a greater volume of water upon the western side of the Continental Divide. The moisture laden winds from the Pacific Ocean here first come in contact with more elevated and consequently colder land-masses, after having passed over the hot plains of Arizona. They are thus deprived of their excess of moisture before reaching the eastern slope.

MEETING OF NOV. 5TH, 1883.

Mr. van Diest read a paper entitled "Eruption of the Volcano Krakatoa, Straits of Sunda," in which he gave an account of the eruption of Krakatoa on the 26th and 27th of August, 1883, the data being chiefly derived from Dutch newspaper reports.

Mr. S. F. Emmons offered some remarks upon the artesian wells recently bored in and about Denver, illustrating by blackboard sketch the basin underlying the city.

MEETING OF DEC. 3D, 1883.

On an interesting variety of Löllingite and other Minerals, BY W. F. HILLEBRAND.

Around the base of Teocalli Mountain, on Brush Creek' Gunnison County, Colorado, there occurs in several mines a cobaltiferous and nickeliferous variety of löllingite of such peculiar appearance as to arrest my attention at a glance. Close scrutiny so strongly confirmed the interest at first excited that a series of observations was undertaken, of which the results are embodied in the following.

The precise locality of occurrence of the specimens examined was unknown to Mr. William McCree, who presented