LICK OBSERVATORY BULLETIN

NUMBER 131

THE CROCKER ECLIPSE EXPEDITION OF 1908.

The Moon's shadow in the total solar eclipse of January 3, 1908, sweeping easterly over the central Pacific Ocean, crossed only two known landmarks: Hull Island, about seven hundred miles north of Samoa, and Flint Island (British), in latitude 11° south, four hundred and fifty miles northwest of the Island of Tahiti. The eclipse would last sixty per cent. longer and the Sun be much nearer the zenith at Flint Island than at Hull Island; and both were equally difficult of access.

On account of our position, on the Californian coast of the Pacific, and in view of our considerable experience in eclipse observation, there existed amongst astronomers a feeling that the Lick Observatory should, if possible, take care of this eclipse. This feeling was intensified by the knowledge that no other observatory was planning to send an expedition. Our duty to others was in harmony with the strong desire to undertake the solution of certain definite eclipse problems and to maintain, as far as practicable, the continuity of our eclipse series of observations.

The subject was brought to the attention of Mr. William H. Crocker early in the year 1907, and he generously undertook to defray the expenses of an expedition to Flint Island—the ninth Crocker Eclipse Expedition—provided a practicable method of transport could be found. There is excellent steamer service between San Francisco and Tahiti; but Flint Island is not on any steamer route. Regular steamers in the South Seas could not be induced, even for a consideration, to go a few hundred miles out of their way, because of insurance complications and of government mail contracts on fixed schedules and over definite routes. The chartering of a steamer exclusively for this purpose was prohibited by the cost. At this juncture it seemed to me that an appeal might

with propriety be made to the Navy Department of our Government to transport the expedition. President Wheeler was pleased to approve this plan and to present my appeal. In response, the department expressed its desire and readiness to meet our requirements fully. It was arranged that the U. S. gunboat *Annapolis*, under command of His Excellency, Captain C. B. T. Moore, U. S. N., Governor of Tutuila, Samoan Islands, should meet us at Tahiti, transport the expedition to Flint Island about four weeks before the eclipse, and, two days after the eclipse, re-embark and carry the expedition back to Tahiti.

Professor E. P. Lewis, of the Department of Physics, University of California, was invited to join the Crocker Expedition by virtue of his great skill in spectroscopic researches, in order that he might photograph the spectrum of the corona with his large quartz spectrograph.

It seemed very desirable that the observing programme should include a study of the heat radiations of the corona, by means of a bolometer. This important line of investigation had been inaugurated at the eclipse of 1900 by Mr. C. G. Abbot, of the Smithsonian Institution Observatory. This fact, and his extensive experience and recognized skill in the use of the bolometer, made him the logical and best observer for this eclipse work. Accordingly, in April, 1907, it gave me pleasure to urge upon Dr. Walcott, Secretary of the Smithsonian Institution, and Director Abbot, of the Astrophysical Observatory of the Institution, the desirability of dispatching an expedition to secure these observations, and to invite the suggested expedition to share in the travel and subsistence arrangements already under way for the Lick Observatory expedition. The proposal met with their approval. The scientific plans of the two expeditions were to be essentially independent, the travel and subsistence expenses

to be shared on the basis of the number of persons in the two parties.

The two expeditions sailed from San Francisco on November 22nd, on the steamship *Mariposa*, of the Oceanic Steamship Company. We numbered eight persons, and there were thirty-five tons of scientific instruments, tents, food, lumber, and general supplies. The party consisted of Director and Mrs. Campbell, Astronomers Perrine and Aitken, and Assistant Albrecht, of Mt. Hamilton; Professor Lewis, of Berkeley; Director Abbot, of Washington, and his assistant, Mr. A. F. Moore, of the University of California.

We reached Papeete, Island of Tahiti, on December 4th. The *Annapolis* came into the harbor on the morning of December 5th. By invitation extended through Governor Moore, our party was joined on board the *Annapolis* by Professor Benjamin Boss, in charge of the U. S. Naval Observatory at Pago Pago, formerly assistant in the observatories at Washington and Albany. Three busy days in Papeete were devoted to transferring our freight to the warship, securing a supply of mineral drinking water, fruit and other perishables, a surf-boat for landing, and picking up our Tahitian carpenter, cooks, and laborers. We sailed for Flint Island on the evening of December 7th.

We approached Flint Island at noon on December 9th, with very considerable anxiety. On the *Mariposa* and in Papeete we heard much of the difficult and dangerous surf landing. The captain of the Tahiti schooner which runs to Flint Island about twice a year explained that landing was possible at only one point, on the northwest side, where a narrow and shallow passage into the flat coral reef had been blasted out; and if the surf were running high at that point we must wait on board ship until it subsided. This was true even when the surf-boats carried nothing more valuable than gunny-sacks full of cocoanuts and copra. The situation would be more serious for scientific instruments.

The visible parts of Flint Island are entirely of coral construction. The waves break on the outer edge of a flat and level reef, whose average width is perhaps two hundred feet, whose height appears to be closely that of quiet water at high tide, and which nearly or entirely surrounds the island. At the outer edge the dip of the reef into deep water is remarkably steep. Sloping up from the inner edge of the flat reef is the dazzling white beach of broken coral, perhaps one hundred feet wide, which encircles the island, except that on the east side there are many irregularities in the way of rough and tilted reefs of solid rock not covered by broken coral. The entire area inside of the white beach consists of broken coral, more or less disintegrated, and is densely covered with trees. The

form of the island is roughly that of a lozenge or kite, with greatest width east and west, nearly a mile, and length north and south slightly over half a mile. Its greatest height, above mean sea-level, is about two feet at the point, near the landing, where the buildings of the leasing company are situated. The average height is said to be thirteen feet.

A few years ago the northern four-fifths of the island were cleared of native trees and planted to cocoanut trees. There are no settled inhabitants. The lessees, Lever's Pacific Plantations Limited, maintain there an English manager and about twenty-five native men and women, all engaged exclusively in the manufacture of copra.

The capable manager, Mr. E. F. Hawk, rowed out to the *Annapolis* with the pleasing intelligence that in his twenty-seven months' residence on the island he had never seen the surf running lower. Accordingly, with the help of the native boatmen and laborers, and of many of the ship's men, the landing in the surf-boats was rushed. By 8 o'clock our forty tons of effects were on the beach and the *Annapolis* had turned back to Tahiti. The contents of our more than three hundred numbered packages were known in detail. This fact, and the placing of the large veranda and several rooms of the manager's bungalow at our disposal, made the starting of life on the island easy.

The site for the station was selected at a point about two hundred feet directly east of the manager's bungalow, in the midst of the cocoanuts; a few missing trees here and there affording just sufficient unobstructed sky for convenient adjustment of the eight groups of instruments. The soil, of old coral, was, nearly everywhere in our camp, covered with rich grass. A tramway running from the landing slip immediately past the camp-site greatly facilitated the bringing up of our heavy supplies. The iron-roofed buildings, and the plantations' and our own steel tanks, affording, to our relief, an abundant supply of pure rainwater, were less than one hundred yards away. The surrounding forest made an efficient brake against winds from all directions; but, fortunately, the wind that rustled the treetops extended its cooling effects to the observers at their work. We were eight hundred and thirty feet (the meridian of the transit instrument) from the outer edge of the reef, and the altitude of the site was sixteen feet above the mean sea-level. The ridge, altitude twenty-two feet, bearing the bungalow and the copra houses, was between us and the beach. The terrible hurricane of 1906 had brought the seas up to the crest of the ridge, throwing some of the buildings off their foundations, but the waves did not reach our position. This was comfort-

ing, inasmuch as the great loss of life and property caused in the South Seas by the hurricane is still the prevailing topic of conversation in that region. The sky when clear was remarkably pure and blue, resembling the Mt. Hamilton sky at its best. All in all, the conditions at the station, local and general, were better than we could have expected, though we were always conscious of the fact that the chances for clear sky at the critical time were not greater than two out of three.

As a result of prior correspondence with, and at the suggestion of, the American Consul at Tahiti, it was planned to provide cocoanut-thatch huts for the living rooms, dining room, kitchen, etc. Lumber for their frames, taken from San Francisco, was quickly put in place by our carpenter and helpers; and the natives brought cocoanut fronds, wove them into thatch, and fastened them on the roof- and side-frames. The eight houses were completed, furnished with the necessary shelves and tables, and occupied as rapidly as each was completed,—all in four days. They were so easy of construction, so comfortable in tropical sun and rain, in fact so thoroughly adapted to their purposes, that the publication of a few additional details may be of value to future expeditions in tropical locations where thatch is available.

Each of the six sleeping-huts was 10×14 feet, with side-walls $7\frac{1}{2}$ feet high. The gable roof was slightly steeper than an ordinary shingle roof. The thatch on the roof should be spread thickly, to turn the rain, but the walls need only a one-thickness covering. We found it advantageous to leave open the two side walls between the limits 6 feet and $7\frac{1}{2}$ feet above the ground, as this afforded better air circulation. A strip of cloth suspended by and sliding on a wire served as a door. Good dimensions for timbers are: Six side-posts, 3×3 inches, let into the ground a short distance; two gable-posts and one door-post, 2×3 inches, also let into the ground; two side-beams, 3×3 inches (with allowance for one-foot gable-roof projections); three cross-beams, 2×3 inches; six rafters on each side, 2×3 inches (with allowance for one-foot eaves); one ridge board, 1×6 inches; two boards on the lower ends of rafters, 1×4 inches. Total, 160 feet, board measure. Diagonal ties in the wall and roof sections, of soft steel wire, $\frac{1}{16}$ inch, can be put in place, with six-penny nails, in a few minutes. The natives usually fasten the thatch in place with strong wrapping twine, but we found six-penny nails more satisfactory in every way. Each hut accommodated the large cots, baggage, and conveniences for two men.

The dining room, 12×28 feet, had a thatch roof and gables, and mosquito-netting ceiling, walls, and doors. Double-door entrances, such as are used in

connection with dark rooms, would have been an improvement in keeping flies out.

On a similar future occasion we should construct two work-rooms, in the same manner, with thatch roofs and open sides, and also a food-supply hut.

While the huts were in process of building, the pier for the Repsold alt-azimuth was constructed and the instrument mounted thereon ready for use; the first time observation having been secured on the evening of December 11th. The grounds were cleared, the instruments and supplies were unpacked in the canvas tents, and the foundations were made ready. The weather was fine, barring short rains, during the first twelve days on the island, and the work of assembling, erecting, and placing the instruments in approximate position and adjustment was well along toward completion. In fact, there remained essentially only the final and delicate adjustments, the repeated trials of the instruments, the training of the observers, and the thousand and one changes in details which go to make up the difference between reasonably good results and those that are really worth while.

The Smithsonian Expedition's observing station was selected by Director Abbot at a point on the beach about 1,200 feet northwest of ours, in order that his bolometric observations prior to the eclipse might have one-half the sky unobstructed by trees. The progress of Mr. Abbot's preparations was analogous to our own.

A few weeks before leaving California we learned with great pleasure that Mr. Francis K. McClean, F. R. A. S., of Tunbridge Wells, England, son of the late F. K. McClean, F. R. S., distinguished contributor, both scientifically and financially, to astronomical progress, would conduct an expedition to Flint Island at his own expense. His chartered ship arrived on December 23rd. The party consisted of Mr. McClean, chief; Messrs. Brooks, Raymond, and Short, of Sydney; and Messrs. Walker and Winkelmann, of Auckland. Their camp adjoined ours on the south-east. We found them to be helpful and congenial neighbors.

Mr. McClean most kindly brought Mr. Merfield of the Sydney Observatory to assist our expedition.

The days following December 20th were for the most part cloudy, but the nights after December 25th were nearly all clear. The preparations, proceeding at a normal rate, were completed in good time on the morning of January 3rd. The *Annapolis* returned on the early morning of January 1st, bringing Consul and Mrs. Dreher from Tahiti to assist in the observations, and an abundant supply of ice for the photographic work.

A room in the bungalow was fitted up as a dark-

room. This had been placed at our disposal by Manager H. Mortimer, who had succeeded Manager Hawk on December 19th.

The forenoon of January 3rd was alternately clear and cloudy, with the clearness much in excess. About ten minutes before the eclipse was total, clouds formed rapidly, until the sky was densely covered. Just as the time-keeper called from his chronometer, "Five minutes before totality," a drenching rain fell, and all seemed lost save honor. At the end of two or three minutes the rainfall began to decrease and the clouds in the east gave signs of breaking. The signal, "Two minutes before totality," was called, as prearranged. Less than a minute before totality the slender crescent of the Sun showed faintly through the clouds, though a moderate rain was still falling. The rain and clouds grew rapidly lighter, and the last drops fell at two or three seconds after totality began. Immediately after the beginning of totality the corona was faintly visible through the thin clouds. These continued to disperse rapidly. During the second quarter of the total phase the clouds were extremely thin, though a thicker cloud obscured the Sun for a few seconds near the end of the second quarter; and during the third and fourth quarters the sky was clear of clouds, but a thin haze could be distinguished. There was no wind.

About ten seconds before totality, the rain having nearly ceased, the order was given to the workman seated on top of the outer of the two towers supporting the forty-foot camera to remove the tarpaulin from over the lens. The order was executed promptly and the remnant of the Sun's crescent was first seen by the observer inside of the camera just one second before totality, and he immediately called out, "One second before."¹ The signal "Go!" was called by the observer at the instant when the crescent disappeared. Such of the instruments as were still covered, awaiting the end of the rain,—for example, the larger celostat,—were uncovered within a few seconds, and the programme of observations was thenceforth carried through without a single slip. The twenty instruments, driven by seven clocks, and the eleven observers and two helpers did their work to perfection. Two spectrographic exposures planned for the fifteen seconds immediately preceding totality were necessarily omitted. The remaining exposures were expected to give good results; and such proved to be the case when the plates were developed, during the following two nights. All of the instruments were in perfect focus and adjustment.

¹ It had been arranged that this observer should call out "Forty-eight seconds before" and "Nineteen seconds before [totality]" when the uneclipsed crescent had certain definite computed lengths; but the impossibility of uncovering the lens while the rain was still falling prevented the giving of these signals.

This eclipse was a very "light" one: not nearly so dark as those of 1898, 1900, and 1905, as observed by the writer.

The repacking of the instruments proceeded rapidly, and, the surf being very favorable, the most valuable articles, such as chronometers, lenses, mirrors, prisms, and clocks, were put on board ship on the morning of January 4th. As soon as the last of the eclipse negatives was dry all were packed with extreme care and sealed in tin. These packages, accompanied by the observers in two surf-boats, were the last to go on board, at 11 o'clock of January 5th. By this time the surf had risen, one of the boats shipped considerable water, and the experiences of both boats in passing out through the surf were certainly exciting. The *Annapolis* headed at once for Tahiti, which we reached at daylight of the 7th.

Our departure from Flint Island was not unmixed with regret. A few members of the party were heard to wish they might remain longer to enjoy the wonderful beauty of our surroundings, a result that strenuous eclipse duties did not adequately permit. Our camp life was wholly devoid of unpleasantness, and there was time on a few evenings for exceedingly pleasant personal experiences. Every member of the party was well every minute, notwithstanding exposure to tropical sun and frequent drenchings; and this happy result is perhaps sufficient comment on the judgment and efficiency of the commissary department.

Six days on the Island of Tahiti were devoted to closing up the local business affairs, to observing for longitude at Point Venus, to sight-seeing, and to several exceptionally agreeable social matters, including a memorable visit to the home of Chief Tati Salmon. We sailed north on the 13th, and after a stormy passage entered the Golden Gate on the 25th. The instruments and eclipse photographs reached Mt. Hamilton uninjured early in February.

The expedition is under many obligations for valued assistance. The first reference must be to the great service rendered by the Navy Department of our Government, acting through His Excellency, Captain C. B. T. Moore, U. S. N., Governor of Tutuila, Samoa, who was in command of the U. S. gunboat *Annapolis*. To meet us at Tahiti, to transport the expedition to Flint Island early in December, to come a second time to the island, reëmbark and carry the expedition back to Tahiti, required an absence of seven weeks from his Samoan post of duty,—an interval but two weeks shorter than our absence from California. Special thanks are due to Governor Moore not only for the able manner in which the department's instructions were carried out, but for the constant personal and

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professional attention that he gave to the needs of the expedition and the comforts of its members.

Cordial thanks are extended also to the able corps of officers of the *Annapolis*:

Lieutenant W. G. Briggs, U. S. N.
Lieutenant H. B. Soule, U. S. N.
Dr. M. E. Lando, U. S. N.
Paymaster J. M. Hilton, U. S. N.
Warrant Machinist J. F. Green, U. S. N.

The petty officers and the gallant crew rendered splendid and heavy service in transferring our freight twice in Papeete Harbor and twice at Flint Island.

Lever's Pacific Plantations Limited, lessees of Flint Island, gave permission to establish the observing station on the island, and instructed their agents in Papeete, S. R. Maxwell & Co. (Mr. Bunckley, superintendent), and to their successive managers on the island, Messrs. Hawk and Mortimer, to meet the requirements of the expedition in every possible manner. These instructions were carried out most liberally. The native labor was available, at my call, for the landing and reëmbarking of the expedition, for the erection of huts, and for many other duties. As previously mentioned, the resources of the bungalow were shared by us for several days, and one room in it was devoted to dark-room purposes. The supply of fresh water was divided with us, half a dozen great turtles were sent in to the commissary department, and many other valuable services were rendered by Messrs. Hawk and Mortimer. Mr. Mortimer assisted in the observations. We earnestly thank the Lever's Pacific Plantations Limited, and their officials, Mr. Bunckley, Mr. Hawk, and Mr. Mortimer, for the services that are here but imperfectly mentioned.

The Government of Tahiti, acting under instructions from Paris, kindly expedited the transfer of our freight and baggage through the port of Papeete. This valued favor was arranged through the good offices of M. Merou, Consul General of France in San Francisco.

Our country is worthily represented by the American Consul in Tahiti, Dr. Julius D. Dreher. During the period of organization he supplied me with reliable information and valuable suggestions on a variety of subjects relating to the work and living arrangements of the expedition. Prior to our arrival he had arranged a score of business matters, in accordance with my statement of needs, which enabled us to pro-

ceed promptly to Flint Island. Dr. and Mrs. Dreher were the guests of the expedition during eclipse week, and they assisted in the observations. The pleasures of our nine days at Tahiti were constantly added to by their thoughtful acts of kindness.

Many favors were extended to the expedition by the Oceanic Steamship Company, acting through Captain H. M. Hayward, of the steamship *Mariposa*, and his officers, through General Passenger Agent Cockroft, of San Francisco, and through Agent Meuel, of Papeete.

Mr. J. Lamb Doty, Mr. F. W. Wakefield, and Mr. and Mrs. F. W. Searby, all former residents of Papeete, supplied useful information and advice.

Professor Benjamin Boss, in charge of the U. S. Naval Observatory at Pago Pago, Tutuila, was an efficient member of the expedition throughout our stay of twenty-seven days on Flint Island.

C. J. Merfield, Esq., of the Sydney Observatory, was a capable and busy member of our expedition during the eleven days that the British party was on the island.

Thanks are extended to Mr. McClean for his generosity in transporting Mr. Merfield from Auckland to the island and return, and for the spirit of comradeship and good cheer which he and all the members of his party supplied.

It was a pleasure to have Professor Lewis in our expedition.

The presence of Director Abbot and Mr. Moore, of the Smithsonian Institution Expedition, was at all times a happy arrangement. It was a great satisfaction to every member of our party that Mr. Abbot's scientific plans were carried out with complete success.

I gladly acknowledge the able assistance of my colleagues, Messrs. Perrine, Aitken, and Albrecht, whose services were always available, both in the preparations and at the station. It has been the lot of Dr. Perrine and myself to be associated in the observation of three eclipses. A veteran of five eclipses, he has no superior as an eclipse observer; and his services, placed unreservedly at my command, were held in high esteem.

Following are articles briefly describing the different instruments and the results secured with them. In many cases the articles are but preliminary, and the details will be published later.

W. W. CAMPBELL.