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ENTOMOLOGICAL AND GEOLOGICAL PAPERS

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UNIVERSITY OF IOWA STUDIES
IN NATURAL HISTORY

HENRY FREDERICK WICKHAM, Editor

VOLUME XI NUMBER 4

ENTOMOLOGICAL AND GEOLOGICAL PAPERS

Iowa. University
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CONTENTS

ANTS COLLECTED BY THE UNIVERSITY OF IOWA FIJI-NEW ZEALAND EXPEDITION

W. M. Mann
Bureau of Entomology, Department of Agriculture

Through the kindness of Professor Dayton Stoner, I have been able to examine the ants which he collected in New Zealand and in Fiji. In addition to new locality records for a number of the endemic Fijian forms, there is a new variety of *Rogeria* (*Irogera*) *tortuosa*, a description of which is included with the list of species.

NEW ZEALAND

Ponera antipodum Forel

Helensville.

Euponera (*Mesoponera*) *castanea* Mayr.

Auckland.

Monomorium (*Notomyrmex*) *antarcticum* F. Smith

Auckland; Helensville; Rotorua; Mt. Rangitoto.

FIJI

Odontomachus hæmatodes (Linné)

Suva; Viria; Walu Bay; Nukulau; Tamavua.

Cardiocondyla nuda (Mayr.)

Suva; Walu Bay.

Pheidole megacephala Fabr.

Suva. Several workers are among Professor Stoner's material. In my paper on the ants of Fiji (Bull. Mus. Comp. Zool. Cambridge, Vol. LXIV, No. 5, p. 403) I stated that I had not taken *megacephala* in Lau and omitted to list it among the species of *Pheidole*. But on the larger islands, especially in the cultivated districts, it is one of the commonest ants.

Pheidole oceanica Mayr.

Circular Road, Suva. One worker.

Rogeria (*Irogera*) *tortuosa* Mann susbp. *stoneri*, new subspecies

Worker. Length 3.50 mm.

Differing from typical *tortuosa* in the absence of striæ on sides of occiput, in which character it resembles the subspecies *levifrons* and *polita* but is distinct from these as well as typical *tortuosa* in the structure of the epinotum, the base of which is longer and less covex and the superior spines broader, widely divergent and curved forward rather strongly instead of being straight as in the other forms of the species.

Type locality. — Tamavua, Suva.

Type. — In the museum of the State University of Iowa.

Cotypes. — Cat. No. 26487. U.S.N.M.

Described from two workers.

Tetramorium (*Tetrogmus*) *simillimum* (Mayr.)

Makaluva.

Tetramorium (*Tetramorium*) *pacificum* Mayr.

Suva; Walu Bay.

Tetramorium (*Tetramorium*) *pacificum* Mayr var. *wilsoni* Mann

Nukulau.

Tapinoma melanocephalum (Fabr.)

Nukulau.

Technomyrmex albipes F. Smith var. *vitiensis* Mann

Nukulau.

Plagiolepis longipes (Jerd.)

Suva; Makaluva; Nukulau.

Camponotus (*Myrmogonia*) *laminatus* Mayr.

Tamavua.

Camponotus (*Myrmogonia*) *schmeltzii* Mayr.

Suva.

Camponotus (*Myrmoturba*) *maculatus* (Fabr.) subsp. *pallidus* F. Smith var.

Suva; Viria.

Camponotus (*Colobopsis*) *dentata* Mayr.

Makaluva.

Camponotus (*Colobopsis?*) *vitiensis* Mann

Tamavua. In Professor Stoner's material are five workers of this species, described originally from the mountains at Nadarivatu, and placed, with doubt, in the subgenus *Colobopsis*.

THE WASP-LIKE INSECTS OR HYMENOPTERA, EXCLUSIVE OF ANTS, COLLECTED BY THE BARBADOS-ANTIGUA EXPEDITION FROM THE UNIVERSITY OF IOWA IN 1918

HENRY LORENZ VIERECK
Ottawa, Ontario

Of the thirty-eight species of wasp-like insects, ants excepted, brought home from Barbados and Antigua by Dr. Dayton Stoner and submitted to me for study, I find that eleven are either new to subdivision 4 of the Neotropical Region or new to science.

LIST OF SPECIES

ICHNEUMONOIDEA

Vipionidæ

Apanteles (*Apanteles*) sp.

A single female that may represent a new species related to *A.* (*A.*) *lævicoxis* Muesebeck, described from Utica, Mississippi.

Antigua, July (Stoner).

Apanteles (*Apanteles*) sp.

A female and male presumably related to *A.* (*A.*) *ensiger* Say.

Antigua, July 15-18 (D. & L. Stoner).

Apanteles (*Protapanteles*) sp.

One female that may prove to be the same as *A.* (*P.*) *floridanus* Muesebeck.

Antigua, July (Stoner).

Microbracon quintilis new species

Female. — Length 2.5 mm.; head above and thorax throughout as if covered with a brownish-yellow lacquer, face and mouth parts yellowish, excepting the blackish tips of the mandibles, antennæ 23-jointed, black or blackish, except for the apical and basal edges of the scape and pedicel which are more or less pale; tegulæ transparent, yellowish, wings infuscated, their veins blackish and yellowish, the costa between wing-base and stigma mostly yellowish, stigma yellowish with a blackish edge, legs, mostly, more or less concolorous with the thorax, end joint of fore-tarsi and all joints of mid and hind-tarsi more or less brownish to blackish, hind tibiæ yellowish except for the apical third which is more or less blackish; propodeum polished with a rudimentary median carina at apex; abdomen yellowish throughout, finely shagreened, almost sculptureless, first tergite with an inconspicuous apical carina, second tergite with an elongate impression on each side of the middle elevated area and with a sublateral impression nearer to the lateral margin than to the median impressions, apical margin of second tergite emarginate, sheaths of the ovipositor longer than the abdomen but shorter than the latter and the thorax combined, end sternite pointed and extending beyond the corresponding tergite.

Allotype — Essentially like the type but with the stigma darker and with the fourth, fifth and sixth tergites brownish black.

Related to *M. dorsator* var. *mellitor* Say.

Type and Allotype — Collection University of Iowa.

Type locality — Antigua, July (Stoner).

Microbracon sp.

One female related to the preceding and probably new to science. Antigua, July (Stoner).

Braconidæ

Bassus, n. sp.

Two female specimens, one broken.

Barbados, June 7 (D. Stoner); Antigua, July (Stoner).

Chelonus insularis Cress.

Many specimens. Antigua, July (Stoner).

Chelonus insularis Cress.

Variety with entirely black carapace. Six specimens. Antigua, July (Stoner).

Ichneumonidæ

Neopristomerus stoneri new species

Female. — Length 7 mm.; head and thorax mostly reddish; antennæ apparently a little longer than head and thorax combined, transfacial line : facial line : : 26 : 21, face and frons virtually equal in width, shining, closely punctured, clypeus yellowish, polished, sparsely punctured compared with the face, malar line apparently as long as the mandibles are wide at base, greatest diameter of lateral ocelli a little shorter than the ocellocular line but apparently equal to the lateral ocellar line, temples shining, convex, apparently impunctate, vertex distinctly punctured, but sparsely; præscutum paler and more closely punctured than the parapsides, pronotum along the upper edge polished and sparsely punctured, elsewhere mostly shining and closely punctured, mesopleura and metapleura mostly densely punctured, veins and stigma mostly blackish, the latter apparently a little less than half as wide as long, legs yellowish to reddish except for the end joint of mid-tarsi, hind tibiæ and hind tarsi all of which are more or less brownish to blackish, denticles rudimentary between tooth and apex of hind femora, longer spur of hind tibiæ apparently more than one-third but less than one-half as long as hind basitarsus; propodeum sculptured much like metapleura, areola apparently twice as long as its greatest width, costulæ joining the longitudinal carina almost at the junction of the basal third of the areola with the apical two-thirds; abdomen polished or nearly so, mostly yellowish to brownish yellow, second tergite a little shorter than the first and together with the apical half of the first and the basal half of the third mostly black or blackish, basal half of the first tergite mostly stramineous, second tergite two and one-half times as long as wide at base, indefinitely longitudinally striate.

Presumably related to *N. melleus* Cushman.

Type — Collection University of Iowa.

Type locality — Antigua, July (Stoner).

Enicospilus purgatus Say.

Many specimens.

Antigua, June (Stoner). One ♂ specimen from the above lot and that may be a variety of *purgatus* goes to *neotropicus* Hooker in Hooker's key because it has only one corneous area in each wing.

CHALCIDOIDEA

Elachertidæ

Euplectrus sp.

Two females of what may prove to be a new species. Antigua, July (Stoner).

Pteromalidæ

Aplastomorpha? sp.

Determined by A. B. Gahan.

One male, Antigua, July (Stoner).

Cleonymidæ

Euchrysia buscki Ashm.

One female. Antigua, July (Stoner). Determined by A. B. Gahan.

Eurytomidæ

Decatomidea pallidicornis Ashm.

Two males that presumably belong to this species.

Antigua, July (Stoner).

Eucharidæ

Kapala sp.

One male that appears to be a new species was taken on Barbados, May (Stoner).

Chalcididæ

Brachymeria ovata Say

Three females. Antigua, July (Stoner).

Brachymeria robusta Cress.

One male and one female. Barbados, May, June (Stoner).

Spilochalcis flavopicta Cress.

Three females. Antigua, July (Stoner).

Spilochalcis femorata F.

Two females. Barbados, May (Stoner).

Vespoidea

Scoliidæ

Compsomeris dorsata F.

Six females and ten males. Barbados, Apr. 1914 (H. A. Ballou); May, June, July (Stoner); St. Kitts, Aug. 15, 1913 (Agr. Supt.).

Tiphia nitida Sm.

One female, two males. Spencers, Barbados, July 1911, June 1913, (Evely).

Psammocharidæ

Psammochares (Pompiloides) coruscus var. *juxtus* Cress.

Female, Antigua, July 14-18.

Psammochares (Pompiloides) subargenteus Cress.

Antigua, July (Stoner).

Psammochares (Pycnopompilus) mundiformis Roh.

Male, Antigua, July 8, (L. Stoner).

Pepsis sanguigutta Christ.

Male, Antigua, June (D. Stoner).

Eumenidæ

Odynerus (Ancistrocerus) n. sp.

Female. Sandhurst, Nov. 22, 1905.

Odynerus (Pachodynerus) grenadensis Ashm.

Female. Sandhurst, Nov. 20, 1905.

Vespidæ

Polistes crinitus Felton.

Females, Antigua, July 1, 8, 1918 (L. Stoner, Stoner). Determined by S. A. Rohwer.

Polistes cincta Le P.

Females, Barbados, May 16-18 (D. & L. Stoner). Determined by S. A. Rohwer.

Sphecoidea

Sphecidæ

Chlorion (Ammobia) ichneumoneum L.

Male, Antigua, July (L. Stoner).

Notogonidea ignipennis Sm.

Male, Barbados, June (L. Stoner).

Apoidea

Halictidæ

Halictus (Chloralictus) sp.

Female and two males, Antigua, July (L. Stoner).

Megachilidæ

Megachile flavitarsata Sm. var.

Male, Antigua, July 15-18 (D. Stoner). Appears to be a variety characterized by having black mid and hind-femora and tibiæ instead of having those parts rufotestaceous.

Megachile concinna Sm.?

Male, Barbados, May 15-18 (D. Stoner).

Xylocopidæ

Xylocopa fimbriata L.

Female, Barbados, June (L. Stoner).

Euglossidæ

Centris versicolor F. race or var.

Female and male, Barbados, June (L. Stoner).

Apidæ

Apis mellifera L.

Workers, Antigua and Barbados (Stoner).

TIPULIDÆ COLLECTED BY THE UNIVERSITY OF IOWA FIJI-NEW ZEALAND EXPEDITION

CHARLES P. ALEXANDER
Amherst, Massachusetts

The crane-flies collected by the 1922 Expedition of the University of Iowa to Fiji and New Zealand have been submitted to the writer for determination through the kindness of Professor Dayton Stoner. The specimens, including the type of *Limonia stoneri,* have been returned to the University of Iowa. For convenience of treatment, the fauna of Fiji is considered separately from that of New Zealand, since there is no relation between the two.

FIJI

The crane-flies of the Fiji Islands are still imperfectly known, the only published papers upon them being two by the writer.[1] The fauna shows a marked endemicism though clearly derived from the larger land masses lying directly to the eastward.

The present collection included three species of the tribe Limoniini, a group which is extremely abundant in number of species throughout the Oriental and Australasian Regions.

Genus DICRANOMYIA Stephens

1829. *Dicranomyia* Stephens; Cat. Brit. Ins., 2: 243.

Dicranomyia illingworthi Alexander

1914. *Dicranomyia illingworthi* Alexander, Ann. Ent. Soc. Amer., 7: 239-240.

This species was described from material taken at Nadi by Dr. James F. Illingworth. The present collection includes three specimens (1 ♂, 2 ♀ ♀) labelled "Fiji, June 1922." The species has more recently [2] been recorded from North Queensland.

[1] Alexander, Charles P. On a collection of crane-flies (Tipulidæ Diptera) from the Fiji Islands. Ann. Ent. Soc. America, 7: 239-246, pls. 34-35; 1914; New or little known Tipulidæ (Diptera). — VII. Australasian Species. Ann. Mag. Nat. Hist., (9) 8: 546-563; 1921.

[2] Alexander, Charles P. New or little-known Australian Crane-flies (Tipulidæ, Diptera). Proc. Roy. Soc. Queensland, 32: 92-109; 1920.

Subgenus THRYPTICOMYIA Skuse

1889. *Thrypticomyia* Skuse; Proc. Linn. Soc. N.S.W. (2) 4: 774.

Dicranomyia (Thrypticomyia) subsaltens Alexander

1922. *Dicranomyia (Thrypticomyia) subsaltens* Alexander; Ann. Mag. Nat. Hist., (9) 10:

This is the species that was earlier recorded as *Dicranomyia saltens* (Doleschall), from material taken by Dr. Illingworth at Nadi. Later material was received from Lautoka, collected by Messrs. Greenwood and Veitch. A study of this material revealed the specific distinctness of the species from *D.* (*T.*) *apicalis* (Wiedemann) which is now known to be distinct from *D.* (*Euglochina*) *saltens* (Doleschall) of the East Indian Islands. The present collection includes a ♂, Walu Bay, Suva, Viti Levu, June 13, 1922.

Genus LIMONIA Meigen

1803. *Limonia* Meigen; Illiger's Mag., 2: 262.

The center of distribution of the great genus *Limonia* appears to be the palæotropical region, from whence it has spread to almost all of the major land masses of the world. In the present collection, a single species was included which is herein considered as being undescribed.

Limonia stoneri, sp.n.

General coloration light yellow; pronotum darkened medially; head brownish black; legs yellow, the tips of the femora conspicuously blackened; abdominal tergites obscure brownish yellow, each with a transverse central band of dark brown, sternites dark brown.

Female. — Length about 10 mm. Described from an alcoholic specimen.

Rostrum brown; palpi dark brown. Antennæ with the scape dark brown; flagellum paler brown, the basal segments with the proximal portion yellowish. Head brownish black.

Pronotum yellow, dark brownish medially. Mesonotal præscutum and scutum yellowish, the former very narrowly and indistinctly darkened anteriorly; scutellum light yellow with a small brown spot on either side of the median line at the base; postnotum yellow, the basal median region more or less darkened. Pleura yellow. Halteres yellow, the knobs dark brown. Legs with the coxæ and trochanters yellow; femora yellow, the tips rather broadly and conspicuously blackened; tibiæ obscure yellow, the tips very narrowly darkened; tarsi obscure yellow. Wings badly injured and their characters can be defined in general terms only; general coloration pale brown, the costal region more yellowish; stigma relatively small, oval, dark brown; veins dark brown, those in the costal region more yellowish. Venation: *Sc* long, Sc_1 alone a little longer than the distance between the tip of Sc_1 and the proximal end of *Rs*.

Abdominal tergites obscure brownish yellow, with a transverse central band of dark brown across each segment; the pale apex of each segment is a little broader than the similarly colored apex; subterminal segments light yellow; sternites dark brown, the subterminal segments yellow. Ovipositor with the tergal valves relatively short and slender, the longer, straight sternal valves blackened at base.

Habitat. — Fiji (Viti Levu).

Holotype, ♀, Walu Bay, Suva, June 13, 1922 (Dayton Stoner).

The type of this interesting species is in the University of Iowa. It is named in honor of the collector, Professor Dayton Stoner.

NEW ZEALAND

The crane-fly fauna of New Zealand is now known to be an extremely rich and varied one. At the time of the signing of the armistice in 1918, the total number of species of Tipuloidea described from New Zealand was less than fifty. Since that time there has been great activity among collectors and a very considerable number of additional species have been described, chiefly by Edwards and the writer. The number of species now known from New Zealand is not less than 350 and the number will be still further augmented with additional collections. The present collection includes only 9 species but this must be considered as being a fair representation of the fauna on the wing at the time the collections were made. The published records for Auckland are very poor and the present list adds several species to the list from this Province.

Genus Dicranomyia Stephens

Dicranomyia ægrotans Edwards

1923. *Dicranomyia ægrotans* Edwards; Trans. N.Z. Inst., for 1921, 54:

Two ♂♂ from Kauri Gully, Auckland, July 18, 1922. The species has a very wide range throughout both islands of New Zealand.

Dicranomyia vicarians (Schiner)

1868. *Limnobia vicarians* Schiner; Novara Reise, Dipt., p. 46.

This is one of the commonest and best-known crane-flies in New Zealand, ranging over most of both islands. The present collection includes a specimen from "The Domain," Auckland, July 14, 1922.

Dicranomyia nephelodes Alexander

1922. *Dicranomyia nephelodes* Alexander; Ann. Mag. Nat. Hist., (9) 10: 84-85.

This recently described crane-fly has been known only from the vicinity of Ohakune, at the foot of Mount Ruapehu, where the types were taken by Mr. Harris. The present collection includes material from Kauri Gully, Auckland, taken July 15-18, 1922.

Dicranomyia cubitalis Edwards

1923. *Dicranomyia cubitalis* Edwards; Trans. N.Z. Inst., for 1921; 54:

This is another widely distributed species, occurring in both islands. The present collection includes material from Kauri Gully, Auckland, July 15, 1922.

Genus Molophilus Curtis

1833. *Molophilus* Curtis; Brit. Ent., p. 444.

The genus *Molophilus* is one of the largest genera in New Zealand, where the number of known species is not far from fifty.

Molophilus multicinctus Edwards

1923. *Molophilus multicinctus* Edwards; Trans., N.Z. Inst., for 1921; 54:

A specimen from Helensville, Auckland, July 17, 1922. The fly has a wide range in both islands.

Molophilus aucklandicus Alexander

1923. *Molophilus aucklandicus* Alexander; Ann. Mag. Nat. Hist., (9) 10:

This species was described from Auckland, based upon material taken by Mr. Harris. The present collection includes a ♂ from Kauri Gully, Auckland, July 18, 1922.

Genus Amphineurus Skuse

1889. *Amphineurus* Skuse; Proc. Linn. Soc. N.S.W., (2) 4: 802.

This large and important genus reaches its maximum of specific development in New Zealand. It is unquestionably allied to *Ormosia* of the Northern Hemisphere but must be considered as being distinct.

Amphineurus perdecorus Edwards

1923. *Amphineurus perdecorus* Edwards; Trans. N.Z. Inst., for 1921, 54:

One ♂ from Kauri Gully, Auckland, July 18, 1922. This rather uncommon crane-fly occurs in the North Island.

Amphineurus, sp., near *gracilisentis* Alexander

1922. *Amphineurus gracilisentis* Alexander; Ann. Mag. Nat. Hist., (9) 10: 563.

A large female specimen from Kauri Gully, Auckland, taken

July 15, 1922, may belong here. It is not possible to determine isolated females in many of the larger genera of Tipulidæ.

Genus TRIMICRA Osten Sacken

1861. *Trimicra* Osten Sacken; Proc. Acad. Nat. Sci. Phila., p. 290.

The genus *Trimicra* occurs on virtually all of the continents and many of the oceanic islands. There is still much doubt as to how many species are involved but the present evidence seems to indicate that virtually all of the many described species are synonymous with the first-described *T. pilipes* (Fabricius). Considerable variation in the length of the 2nd anal vein in these various so-called species makes it necessary to investigate certain of them more closely, since this character of length of the 2nd anal vein has been used as a generic and subgeneric criterion in other groups of the Eriopterini.

Trimicra inconstans Alexander

1922. *Trimicra inconstans* Alexander; Ann. Mag. Nat. Hist., (9) 9: 148, 149.

Several specimens from Helensville, July 17, 1922; one ♂ from Rotorua, vicinity of hot springs, July 31, 1922. This latter has been recorded by Professor Stoner[3] as feeding on the algæ growing on the hot sand in the near vicinity of the hot, bubbling springs.

[3] Stoner, Dayton. Insects taken at Hot Springs, New Zealand. Ent. News, 34: 88-90; 1923.

PHOTOGRAPHIC PRACTICE FOR FIELD GEOLOGISTS

CHESTER K. WENTWORTH
University of Iowa

INTRODUCTION

FOREWORD

In preparing the following paper the writer has received suggestions and criticism from a number of geologists and students of photography. Considerable difference of opinion existed among those who read the preliminary manuscript in regard to the desired emphasis on different points and on the length of treatment but in general suggestions made were followed in revising the paper. Especial thanks are due to R. B. Wylie, J. J. Runner, and E. T. Apfel of the University of Iowa, to F. E. Wright of the Geophysical Laboratory at Washington, and to E. A. Shuster of the Photographic Laboratory of the U. S. Geological Survey for helpful comments and criticism.

PURPOSE OF GEOLOGICAL PHOTOGRAPHY

There are two general classes of photography: the one, which may be designated as artistic photography, being practiced primarily for esthetic purposes; the other, known as record photography, being devoted to practical ends in the pure and applied sciences. Photography as practiced by geologists belongs essentially to the latter class and it is in the main from the practical standpoint that it is considered here. Photographs are used in the presentation of the facts and principles of geology. These may be presented as a part of an original contribution to the science or they may be presented as parts of a treatise representing current knowledge in one or all branches of the subject. In either case the photographs may accompany a printed book or paper or may be copied in the form of lantern-slides or prints to illustrate an oral discourse. More frequently than otherwise the use of photographs renders the presentation not only more pleasing but also effects a considerable economy of time and space. In the case of most sorts of bare facts the effectiveness of presentation is probably greatest when the phenomena are actually seen by the person who is to be informed. Next in order is the viewing of a good picture and third and least effective as a single means is the text description. A combination of the latter two is probably more effective than either alone and next best to the combination of observation and discussion of the phenomena at first hand. In addition to their use as single permanent records photographs are sometimes of great value to show progressive changes such as those which take place in vegetation, processes of erosion or deposition and the like and are then taken in series.

Importance to Field Geologists

The importance of a knowledge of photography to field geologists is apparent when it is recognized that, except for the most general views of topographic features and for photographs of common features which may be recognized by inspection, the great bulk of photographs of value in geologic investigations or teaching must be taken by the geologist most familiar with the phenomena to be illustrated. It is the exception rather than the rule when it is possible for the geologist to designate the features of importance and have them photographed by a professional photographer. Not only must the field investigator himself determine the features of which pictures are to be made but he must decide upon the point of view, the arrangement if they are movable, and the other conditions so far as they may be controlled and he alone is able satisfactorily to decide upon the fitness of the resulting pictures. It is true that that part of the picture making which may be called the dark-room technique may be advantageously turned over to others. It is very desirable, however, that the geologist be versed in the general principles of developing and fixing of negatives and of making prints for he can then most intelligently recognize the sources of imperfection in resulting pictures and improve his own technique or criticise that of the dark-room as the case may be. Consideration of the dark-room technique is beyond the scope of this paper and moreover is adequately treated in an extensive literature since that of use to geologists is no different from that of other branches of record photography.

In the case of field procedures, however, there seems to be room

for description of the methods and equipment which have been found most useful. Much that appears below is applicable to other branches of out-of-door record work such as that done by students of botany, zoology and other branches of natural science.

Diversity of Photographic Conditions in the Field

If field photography may be said to have any essential peculiarity it is the extreme diversity of conditions which are confronted. These include variations of sunlight due to differences of time of day and condition of the atmosphere as well as those due to differences in latitude and season of the year. Subjects vary enormously in their colors, inherent contrasts and brightness. Many of these are quite fixed and immovable and are in positions none too favorable for successful photography. Even in those cases where the subjects might more advantageously be photographed under better conditions of light or at another time of day it is not commonly practicable for the field geologist to wait for the improved conditions. The observation, note-taking, collecting and other operations of field investigation are so onerous that most commonly the geologist will not have occasion to return to the exact spot and should be prepared to secure the best possible results in photography at the time he first studies any given feature.

Limitations in Equipment [1]

The geologist's task is made more exacting by the fact that he can usually carry but a limited amount of equipment, a considerable part of which is for other than photographic purposes. With the very restricted amount of photographic equipment at hand he must photograph a wide range of subjects under conditions far more diverse than those met by most commercial photographers. It is clear that success in this work demands considerable knowledge of photographic principles and careful choice of equipment as well as painstaking attention at all times to the technical details.

EQUIPMENT FOR FIELD USE

The Camera

The writer does not propose to discuss the relative merits of many different models of domestic and foreign hand cameras which

[1] It has seemed best in the present paper to treat the subject of field

are available. It will be sufficient to point out the inherent advantages and disadvantages of a few types as related to different sorts of field photography. Cameras of interest to field geologists may be grouped in four classes. These are

1. Roll film folding cameras
2. Plate back folding cameras
3. View cameras with long extension
4. Reflecting cameras

Perhaps the first choice to be made is that between roll film cameras and plate-film pack cameras. The former are unquestionably more convenient to manipulate and carry and the roll films are more readily obtained in small towns than plates, cut films or film packs. The roll films are far lighter per exposure than plates or cut films and the roll film camera is somewhat less bulky than the plate camera of the same nominal size. For the geologist who wishes to do critical work in both detail and distant views the plate camera has certain distinct advantages among which are the use of the ground glass for focusing and composition, the use of various grades of films or plates such as those of varying speed, contrast or color sensitivity.

The ultimate choice between the roll film and plate cameras depends on the personal attitude of the user toward photography. Not all aspects of field technique will be accorded equal attention by different persons and by some photography will be treated as a necessary part of the field work but not as an avocation as it will by others. For the geologist who wishes to cope with the unusual and difficult subjects and to use different grades of cut films and a convertible lens the plate camera is essential. On the other hand, using the same care on the details, negatives of equal quality can probably be made from four out of five subjects with the roll film type of folding camera. The scope of this sort may be greatly increased by the use of auxiliary lenses as previously described by the writer.[1]

There are opportunities for a considerable range of choice in selecting a roll film camera and it is sufficient to point out that a brilliant view finder, rising and falling front, substantial bed

photography from the standpoint of travel on foot. Travel by automobile where it is practicable permits transportation of more elaborate equipment but the same principles hold in the field practice.

[1] Wentworth, C. K. (Adapting a Short Bellows, Roll Film Camera for Detail Work.) Journal of Geology, Vol. XXX, pp. 158-161, 1922.

and focusing mechanism and a dependable shutter are the important features. There is an even greater diversity of type in plate cameras. Box cameras of the Corona type are very useful for all kinds of out of door work close to headquarters or when working by automobile but are, even size for size, rather bulkier than other types and are not so convenient for foot travel. There are a number of small plate-back folding cameras, especially in the foreign makes, which have longer bellows extension to facilitate short range focusing and the use of single components of convertible lenses. These are very useful in combining portability with the advantages of ground glass composition and use of various grades of plates or films.

Reflecting cameras of which the Graflex may be taken as a type are unexcelled for photographing moving objects or those that must be caught in certain transitory positions. Some of them are fitted with long bellows extension and other adjustments and when used with a tripod are equally satisfactory for still pictures. The mechanism throughout is usually high grade and for general purposes they must rank high. At the same time they are necessarily heavy and bulky and will hardly be chosen by the geologist who must carry his equipment on foot. For most geologic pictures speed is not essential and the shallowness of definition forced by the use of wide apertures is so objectionable as to be justified only where the speed is absolutely necessary. In all other cases the extra weight of the Graflex which is aimed mainly at this one object serves no purpose.

In choosing a camera for every day field use perhaps the first question to be considered is size. Probably the bulk of pictures taken for geologic illustration are made with cameras of the $3\frac{1}{4}''x4\frac{1}{4}''$ or $3\frac{1}{4}''x5\frac{1}{2}''$ sizes. The writer believes that one or the other of these sizes will be found more satisfactory than any larger or smaller sizes. Much has been written on the general plan of making sharply defined small negatives with a high grade anastigmat lens and enlarging the image in printing. Theoretically the plan has much to commend it. Equipment is much lighter and less bulky, the short focus lens has greater relative depth, film is less expensive and easier to store than in the larger sizes. Satisfactory enlargements for ordinary pictorial purposes can undoubtedly be made from small negatives for purposes of scientific record. However there are so many sources of defective definition or of other flaws in the negative that the writer believes in the long run the average negative is none too good and should be large enough to give by contact printing an image of sufficient size to serve as a moderate sized illustration in a published paper or large enough to serve as a lantern slide for projection. The labor and expense of printing by enlargement is considerably greater than that by contact and the writer does not know of a single geologist who possesses an extended series of good field pictures made wholly by enlargement from the negatives.

The Lens

There is a wide range of choice in lenses. A lens at least as good as the widely known Rapid Rectilinear is essential. For a few geologic subjects greater speed than is given by the f/8 aperture is needed. It is a source of much satisfaction to have a high grade anastigmat lens for these occasional needs but the writer believes the desirability of a fast lens can be greatly exaggerated. It seems to him profoundly true that a fine series of photographs illustrating geologic features reflects patience and skill on the part of the photographer to an enormously greater degree than it does the quality of the lens he used. From inspection of most such pictures it is quite impossible for anyone to tell with what sort of lens they were taken and compliments on ones lens based on admiration of good photographs of the features ordinarily taken by geologists commonly indicate only ignorance of the most elementary photographic principles. By the foregoing statement the writer has no intention of appearing scornful toward high grade lenses but merely wishes to emphasize the view that understanding of the equipment the operator has in hand is of vastly more importance than the price he paid for it.

There is so much popular misunderstanding on the subject of lenses that a few words on elementary principles will not be amiss at this point. A simple meniscus lens such as that of a small pocket magnifier has six principal types of defect or departure from perfect definition. There are spherical aberration, chromatic aberration, distortion, curvature of field, astigmatism and coma. These may be briefly defined as follows:

Spherical aberration — Caused by the convergence of rays passing through the outer parts of the lens at different distances from those passing through the central parts.

Chromatic aberration — Caused by the convergence at different distances of rays of different colors, hence of different wave lengths.

Distortion — Caused by convergence of rays from objects not on the lens axis at distances from the axis not strictly proportional to the distances of the objects from the axis. Straight lines not passing through the center of the field become slightly curved in the image.

Curvature of field — Consists in the convergence of rays from outer points of a plane field at different distances from those from the central parts, thus making the focal locus a curved surface symmetrical to the lens axis rather than a plane.

Astigmatism — Consists in the establishment at different distances of images of lines radial to the lens and those tangential to the lens.

Coma — Consists of a blur produced by lateral spherical aberration of rays passing obliquely to the axis of the lens.

In high grade lenses these defects are greatly reduced in amount by the combination of simple lenses of different forms and made of glass of different refractive and dispersive qualities but they are never completely eliminated. All these defects are much reduced in actual practice by using small apertures.

The six defects mentioned above are so interrelated that an attempt to achieve partial perfection by the elimination of any one usually results in increasing one or more of the others. For any lens the so-called speed (a most misleading term) or relative aperture is the ratio between the largest aperture at which the lens will give satisfactory definition and its focal length. Satisfactory definition is commonly considered to exist when the image of no point is dispersed by the combined defects over a circle of greater than 1/200 inch in diameter. Most lenses are so mounted that no larger apertures may be used and the "speed" is thus a statement of the largest working aperture. There is no practical difference in the rate at which light passes through the glass of different lenses nor in the amount of light transmitted by an aperture of unit size.

Depth of definition is not an inherent quality of a lens. It is a variable condition controlled by the aperture in use and the focus of the lens and is the same for all lenses of the same focus and at the same aperture. The very great and very useful depth of definition of fixed focus cameras of the Brownie type is a necessary consequence of their small maximum apertures and relatively short focus and may be duplicated by using proper adjustments on any small hand camera.

A convertible lens is one so designed that one of the two components may be used alone. In some lenses the two components are identical and either may be used with the same result; in others known as triple convertible the two components are of different focal lengths and thus by using either alone or the two together offer three focal lengths. The advantage of the choice of focal lengths is very great in controlling the size of the image when the viewpoint is fixed by topographic or other conditions. The longer focal lengths give larger images from a fixed viewpoint and have the quality of giving less pronounced perspective than the shorter focal lengths.

Very short exposures are not essential for most geologic subjects since these are stationary and excessively large apertures are undesirable because of the shallowness of definition. The writer feels that a lens of f/6.3 aperture and possessed of low distortion and curvature of field is as good as any for field use.

An excellent description of many of the well known types of lenses is contained in the article on Photography in the Encyclopedia Britannica, 11th Edition.

Closely related to the question of lenses is that of shutters. Lenses of larger apertures than f/8 are commonly fitted with shutters in which a spring previously set is released by the trigger whereas those of f/8 and less, commonly have the energy furnished and release effected by the same movement of the hand. When the former type is used in the field the writer believes quite as much benefit is derived from the advantage of the compound shutter as from the superior lens. The latter type of shutter rarely has actually the speeds nor the range indicated, the high speeds being slower and the lower speeds faster than those shown. The former type, if in good condition, is far more likely to show close agreement between indicated and actual speeds and furthermore is susceptible of more accurate adjustment. The focal plane shutter is indispensible for cameras of the Graflex type but as mentioned above these are not considered to be so convenient for general geologic work.

There are various accessory devices which have been developed

by various makers, some of which are essential and others of less value. The rising and sliding front is valuable and will be found on most cameras having other necessary features. The writer has made little personal use of the autographic features since he prefers to add photographic notes to others constantly made in the field note books but other geologists prize the feature highly. The range finder with which some cameras are equipped is probably of less value to the geologist than to the general public since he probably estimates distances with considerable accuracy by inspection. The same may be said of a level. The writer finds that sighting on the horizon or comparison with the vertical lines of trees insures reasonable alignment of the pictures for ordinary purposes. The use of a precise level for phototopographic work of any sort is of course quite another matter.

Plates and Films

There is a wide variety of plates and films of various makes available at the present time, of which practically all may be regarded as of excellent quality. Roll films and film packs are commonly of one speed and orthochromatic to a moderate degree. Some of the film of film packs appears to carry a slightly thinner emulsion than the roll film but this difference is of relatively small importance on most subjects. Glass plates in all the standard sizes may be had in a number of speeds and degrees of contrast and with orthochromatic and panchromatic color-sensitive emulsions. A similar variety is available in the newer cut films which are extensively used by many commercial and amateur photographers. The principal advantage of the cut film over the plates aside from the obvious reduction of weight and danger of breaking is that in the film halation is practically negligible due to the lesser thickness and reduced reflections.

A few general principles may be noted here. Very rapid plates or films commonly have somewhat coarser grain in the emulsion and also have considerably less latitude. The slow process plates have likewise much less latitude. Where special purpose films or plates are needed they serve admirably but it must be remembered that in many instances their special properties have been secured at the sacrifice of some other feature. Color-sensitive plates and films have revolutionized the photography of certain objects and will undoubtedly increase in use in the future. In conjunction with the proper filters they permit the portrayal of any object in terms of a small part of the total light reflected from it and that of a relatively narrow range in wave length. To see the possibilities in this field one has but to make visual examination of various natural and artificial colored objects through various photographic filters. Photography in natural colors is made possible by a number of processes but it will not be considered in the present paper for two reasons; first, because the writer has had no personal experience with these processes and second, because it appears unlikely that it will be used to any considerable extent by geologists in their professional work in the near future.

The materials to be used will have been in part determined by the choice of a camera. If this was of the roll film type there is relatively little choice to be made in the matter of films. In many, one might say most, cases it is desirable for the geologist to secure a goodly supply of film before going to the field and in such instances this is best packed in foil or other airtight "tropical" container.

If a plate camera is used and many photographs are to be taken incidental to long daily trips the film pack will be desirable since the weight is slight in comparison to that of either plates or films in separate holders. If not over six or eight exposures are made in a day separate holders containing cut film can well be carried. In this case some may be of ordinary portrait or commercial grade and a few orthochromatic or panchromatic. Orthochromatic film is being increasingly used for general purpose work as well as for special subjects and the writer feels that it might profitably be substituted for most routine field work with plate cameras. The same is, of course, true of plates with similar emulsion but it is unlikely that many geologists will prefer the plates to the lighter cut films. Panchromatic films aside from being slightly slower than other grades are equally useful on all subjects and are essential if the deeper filters such as red, orange and green are to be used.

Tripods and Supports

Some sort of tripod is essential as is urged by the writer at great length elsewhere. On the score of weight the tripod is always something of a burden and there seems to be little escape from this difficulty. Many different sorts of tripods have been devised in America and abroad with object of securing the greatest rigidity

with the least weight. From this standpoint the folding wooden tripod is probably the best but it is less convenient and more bulky than the tubular telescopic metal tripods. The latter deteriorate in stiffness more rapidly than the wooden tripods in the course of the neccessarily rather rough usage attending field work but appear to be about as good as any available for the lighter cameras. For the larger view cameras wooden tripods of ample size are very satisfactory.

A number of types of clamps and universal joints are obtainable for the smaller cameras. Of these the writer has found the form designated as the Optipod by the Eastman Kodak Company to be very convenient both as a universal joint for use with the tripod and also as a substitute for the latter in connection with some other support. By modifying the shape of the jaws to a slight extent this instrument can be made to take a tighter grip on objects not injured by marring and has been used extensively by the writer in conjunction with his geologic hammer. The latter can be driven into a slight rise on the ground, or into a fence post or tree and the optipod then attached to the handle. Another method is to build a rude tripod or lean-to pile of any available sticks and clamp to some part of this. By such methods the writer has found that in some types of country it was possible to get on without carrying the tripod and still to support the camera for time exposures for nearly all pictures. Some sort of universal joint is worth its weight in places where it is difficult to find footing for the tripod and at the same time direct the camera with accuracy toward the desired subject. With the joint one can use the available footing even though it be very unsymmetrical and then do the aiming as another operation with the adjustment afforded by the ball and socket. If many detailed pictures of small objects lying on the ground or in out of the way places are to be attempted the universal joint is indispensable since by its use the camera may be pointed directly down or in any other direction with equal ease.

The writer has not seen an equally satisfactory universal joint for larger cameras on the market but has used a simple one of his own construction for a number of years. This consists of a simple right angle of $\frac{1}{4}''$ x $1\frac{1}{4}''$ band iron with arms of 2″ and 6″ respectively. Each arm has toward the end both a clear $\frac{1}{4}''$ hole and a hole tapped with $\frac{1}{4}''$-20 thread (approximately the standard socket thread). With the angle is an extra tripod screw which is kept in one of the tapped holes when not in use. The angle is clamped at the top of the wooden tripod by means of the tapped hole in either arm and the camera then clamped sideways to the other arm by means of the extra screw and clear hole. The angle is thus rotatable on the tripod and with the motion of the camera on the other arm provides for it a full alti-azimuth mounting which is far more rigid then would be a clamp with movable parts. The device weighs nearly a pound but is still proportionately light compared to the camera it supports.

Some tripods may be fitted with tilting heads which serve the same purpose as universal heads. As in the case of tripods themselves these are difficult to construct of the requisite strength combined with lightness and are worth examining with care or trial in actual use before purchasing.

Stereo photography is becoming more popular among amateur photographers and is of great value to geologists in certain instances. It is doubtful if stereo cameras with their necessary extra bulk will be carried for routine work but occasional stereo pictures may be taken by moving the camera between two successive exposures. A light, flat metal link of a length half the desired shift has been used by the writer and makes the shift more easily achieved than if the whole tripod were to be moved. Dr. F. E. Wright [1] suggests a shift of from one to five percent of the distance to the principal object to be photographed.

Exposure Meters, Tables and Computing Devices

There are many mechanical devices for determining the exposure to be given under any set of conditions. There are many very successful photographers who estimate exposure as the result of experience without reference to any sort of artificial aid. The writer has used a few of the devices which are available and has also done considerable satisfactory photography without any of them. He feels that the best procedure for the average person is to use some one of the many good calculating devices and at the same time for each picture estimate previously to using the calculator the exposure he would give. He can then compromise between his own estimate and the reading of the calculator and let the finished picture be the proof. On the one hand the constant effort on the part of the operator to forecast the result of the calculation, which may be considered in most cases reasonably correct, and on the other hand his observation of just how his estimates differ justifiably from the calculated ones prove to be very effective in building up a vivid exposure instinct or judgment.

[1] Wright, F. E. Private communication.

The various exposure determining devices may be divided into four classes. The first class consists of meters proper or actinometers which make a direct measurement of the light at the time the picture is taken by means of sensitized paper. These are useful in connection with landscape or architectural photography but are less satisfactory in detail photography where one is concerned with the light reflected by a small object. The second class includes the type of meter in which the light is judged by viewing through a wedge or series of screens of variable density. These have the advantage that one can deal with the light directly and exclusively from the subject. They are subject however to the disadvantage that the human eye varies greatly in its susceptibility to light under varying conditions. Even with the precaution of allowing the eye to come to rest by closing it for a time there is doubtless much variation in the readings obtained from identical lightings of the same subject wih variations in the condition of the eye of the observer. In spite of this drawback this type of meter is probably among the most useful. The third type consists of the numerous calculators, circular and linear. These are all similar in that they take account of condition of the sun, time of day, season of year, nature of the subject, speed of the film and aperture of the lens. They also employ in common the logarithmic slide rule principle in the computing. They differ in the arrangement of the various factors and movable parts and in the range and manner of statement of the various factors. They are the most convenient and portable of the four types and illustrate most vividly the effect of the various factors in controlling the tremendous range in practical exposure times under various conditions. The fourth type is the exposure table such as that issued by American Photography. These tables are more complete than any of the calculators and handle a wider range of conditions. They consist essentially of a series of logarithms (to the base 2 or 4) of the values of the several factors which may conveniently be added mentally to secure the logarithm of the exposure.

Miscellaneous Accessories

For work with the larger view cameras a focusing cloth will be needed. Rubber backed bellows cloth is more completely opaque but plain black cloth is less warm to work under and will do for most conditions. With some ground glass cameras a small collapsible hood is attached and in these a sufficient view of the image is available without the focusing cloth.

A changing bag permits loading and unloading of films in the daytime and will be needed where many pictures are to be taken in one day on cut films or plates. At night away from bright artificial light one may find many places where plates, even of panchromatic grades, may be changed safely, if one works quickly and with due care.

A self timer is useful in some instances. For example if one wishes in the picture to point to a certain contact and is working alone he may by means of the self timer be able to appear in the picture. In other cases where brush has to be held aside the self timer may be used to advantage.

The choice of ray-filters will depend on the films which are to be used. If one or two only are carried those in slip-on mounts are most convenient. For using a larger number interchangeably the writer has a small cell which slips on the lens cell and holds in turn the filter by means of a light spring ring. The filters used are unmounted but cemented in glass. He has carried six of these filters in chamois pockets in a metal pill box daily for nearly twelve months in the tropics without breakage and without serious deterioration.

For most subjects a yellow filter (K_2 of Eastman Co.) is best, next to this the orange (G), red (A), deep red (F), and green (B) are useful in the order named. All of the last named can be used only with panchromatic films or plates. Exposure factors and other data for the use of these filters can be obtained from the makers.

Lenses should be kept clean, preferably by good protection rather than by wiping. A small and thin lens cap is useful for this purpose especially in the tropics and in damp situations. If absolutely necessary to wipe a lens, the dust should first be dislodged by holding the lens inverted, and brushing or flicking the dust from the surface as it may contain hard particles which would scratch

the glass. A clean piece of soft cloth may be used to wipe the surface gently but tissue paper or special lens paper is best of all and if protected will always be clean.

Methods of carrying the camera and accessories will differ according to personal choice. To some a carrying bag seems most convenient and others prefer a sling case or some sort of belt attachment. The writer cannot refrain from urging the adoption of some systematic plan for the transportation of the camera and other photographic equipment and the provision of small cloth or leather bags or cases to exclude dust and afford reasonable protection to the instruments. At best field work is hard on instruments of all sorts but the condition of some cameras, compasses, barometers and handlevels the writer has seen in the hands of geologists was due to lack of even ordinary care and attention in the matter of drying and cleaning. Several of the instruments mentioned above cost as much and are worthy of the same care as a good watch.

FIELD PRACTICE

Pre-Field Testing

Unless one takes into the field only equipment of which he has made frequent and recent use it is desirable to make a few tests to make sure that it is in working order and to become accustomed to any pecularities it may possess. There are a number of defects not readily noticed which might easily cause the entire loss of many pictures if not detected. Leaks which admit light may occur in the bellows or in other parts of the camera or the slides or backs of plate holders and film pack adapters may be similarly defective. Lenses sometimes become loosened or uncemented and cause poor definition or flare. The focusing scale may not be properly placed or may not be accurately graduated. The upright yoke which carries the lens not uncommonly becomes bent and changes the focus relation, especially in cameras with short bellows. The focus may readily be tested on a roll film camera by removing the back and laying a ground glass strip with its ground side in contact with the rollers. If the ground glass is not convenient a strip of tracing cloth or paper stretched taut may be used.

One of the features most in need of testing is the shutter. This should work decisively and if not with times as marked the actual times should be known. There are various methods of testing the speed of shutters of which a few will be mentioned. A bicycle wheel carrying a single bright object on its outer edge can easily be rotated at a speed which is known within 5 percent or less. This should be photographed from a point near the extended axis of the wheel using the several speeds to be tested. The aperture and lighting should be such as to give a fairly strong image for the bright spot. After developing the film or plate the amount of angular motion can easily be measured and the speed computed. With a little planning all the speeds marked can be tested on one or two films if the general lighting is dull enough so that most of the view is much underexposed and the camera is pointed differently for successive views. Any piece of machinery rotating at known speed and carrying a bright spot (such as a thumb tack illuminated from behind with a strong light) can be similarly used if the speed be of about the right value. From one-fourth to a full revolution during the exposure is best for accurate measurement.

A very simple method is to arrange two carbons to give a small arc light on an alternating current circuit. If this light be photographed in a dark room while swinging the camera about slowly the image will be a line of dots. In the case of a 60 cycle circuit there will be 120 flashes per second and exposures from 1/50 up to two or three seconds can be measured with reasonable accuracy.

A falling body or a pendulum may be used but the computation would be somewhat more difficult than in the foregoing examples. Various other methods will occur to anyone needing to test a shutter, according to the facilities he has at hand. The writer has never attempted it but a satisfactory test could probably be made by photographing at short range an automobile traveling at known speed.

Placing the Camera

In placing the camera the first and prime consideration is visibility of the feature it is desired to portray. In open country this matter offers little difficulty but in a wooded region the vegetation sometimes interferes either with getting a view out from the camera stand to a distant object or with getting a view in toward a shaded rock feature. Another factor which has to be considered

at the same time is the support for the camera. If the picture is to be taken as a snapshot this part is easy but for a time exposure one has to have suitable footing for the tripod or some object to which to clamp the camera. If a tree or other solid object is at hand the camera may be blocked upon it or held against it with or without blocking in almost any position. Such a position may prove a little awkward for focusing on the ground glass but in most cases this may be done "free-hand" and such slight errors as are present in the focus are more than taken care of with the increased depth resulting from using a small stop. If one uses a tripod a universal joint will be found extremely convenient in orienting the camera in difficult situations after some sort of footing for the tripod has been found.

A third factor which should be taken into account so far as possible under the limitations imposed by those of visibility and support is that of most favorable viewpoint and lighting. Features which can be conveniently visited at any time of the day enroute to more distant places or which are of sufficient importance should be studied in order to choose the most effective light conditions. Practically all the features which geologists have occasion to photograph will be found to be more clearly outlined in the oblique rays of the mid-morning or mid-afternoon sun than in that of noonday and with a reasonable amount of intelligent practice in estimating exposure good pictures may be taken from sunrise to sunset. Low terraces and similar features are frequently uniformly grass covered and hardly distinguishable except in early morning or late afternoon light. In the case of detail views of rock surfaces the choice of time depends on the attitude of the surface in relation to the sun. Such subjects as glacial striæ or slicken-sides which depend on very sharp oblique light for their proper illumination are not always situated in such a position that the sun ever strikes them properly. (Figure 1). These may sometimes advantageously be illuminated with an artificial light at night or by means of a mirror after shading them from the direct natural light.

In photographing objects directly toward the sun, which is sometimes necessary or even desirable, care must be taken to shade the lens, especially if a wide aperture is used. Many subjects will appear best when entirely in the shade. This is particularly true of such features as bedding, schistosity or other structures in which the chief distinction between different parts is a color difference rather than a difference in relief or configuration. If such a surface has any considerable irregularity and is photographed in bright sunlight there is danger that the essential color differences will be entirely subordinated to the incidental light and shade distinctions.

In addition to the problems of placing the camera under normal conditions there are those of keeping it placed in a high wind or keeping it dry in rainy weather. If camera or holders become wet superficially they should be wiped at the first opportunity and laid where they can become thoroughly dry. Salt water and spray are particularly insidious because the deliquescent salts maintain a condition of stickiness and are rust breeders in addition to the damage to films. Camera and film cases of rubber coated cloth are very useful in wet regions.

Focusing

Objects 100 feet or more away offer no problem in focusing but for nearer objects the camera must either be focused on a ground glass or by means of a scale set to the estimated distance. If the view involves a considerable range of distances for near objects one should focus or set to some feature which is about midway on the focal scale of the whole field of view and use a very small stop. If it is desired to include distant objects and foreground in the picture the focus should be set midway (on the focus scale) of the two distances and the lens stopped down to the necessary small aperture. (Figures 2 and 3. See table of depths of definition).

It is desirable in many detail pictures to place some object of known size in the field of view to serve as a scale. In such a case the object, such as the geologist's hammer, his pencil or some other convenient object should be placed as unobtrusively as possible toward the bottom or one side and objects of unusual character or of temporary interest avoided as much as possible. In views of large rock exposures a human figure makes a good scale but should not be so placed as to divert interest from the geologic features. (Figure 4).

Choice of Plates or Films

If one is operating a roll film camera the choice may be considered to have already been made. With a plate camera there are a number of grades of film or plate which may be used according to the nature of the subject. Probably the best for standard use is some good make of orthochromatic cut film. For a few subjects such as rock exposures which are wholly in sunlight or similar objects with little color variation there is little purpose in using a color filter but most pictures will be considerably improved by the use of a medium filter such as K2. Clouds will be made more distinct and visibility through nearby haze increased by such a filter. Views which unavoidably combine brilliant sunlight and rather deep shadows can usually be taken more successfully with a filter than without. Very distant haze-obscured skylines require a deeper filter such as the red F and a panchromatic film for their successful delineation. (Figures 5 and 6). The lighter red A and the orange G are occasionally useful in taking geologic subjects and more rarely the green B filter. (Figure 7).

For the photography of bright colored objects, such as flowers, animals or other natural objects filters and orthochromatic or in some cases panchromatic films are essential. It is rarely that the geologist will have occasion to seek exceptional rapidity in the films he uses and it is well to remember that the medium speeds of film have greater latitude and finer grain than the faster ones. In a very few instances the use of process films with their very great contrast is desirable but it should not be undertaken unless other methods have failed to secure pictures of very flat subjects and one can check upon the films by having them developed at once. The latitude of these films is so slight that the exposure must be estimated with much greater care and the contrast is so great that objects with any range of light and shade are likely to produce disappointing results.

Determination of Exposure

The factors involved in determining the length of exposure for a given picture are as follows:

1. Latitude
2. Season of year
3. Time of day
4. Condition of sky and atmosphere
5. Distance of object
6. Illumination of object

7. Color and lustre of object
8. Speed of film
9. Filter
10. Aperture of lens

Fortunately the calculation of exposures from these ten factors does not need to be carried out with great numerical accuracy. In fact in practice several of the factors can be ignored most of the time if the operator is alive to the relative importance of all the factors and knows when a given factor becomes of large importance. For operations from day to day, the latitude and season of the year are constant and need be taken into account but once. The speed of the film is another factor which need be considered only as one changes to another grade. Other factors may be combined in making rough mental calculations. For example the distance, illumination and color of objects may all be combined under the general head of subject. For a number of years the writer has used a scheme for simplifying the calculation of exposure which has proved to be very useful. It is based on the principle that the exposure time and the area of the aperture are inversely proportional for a given set of conditions. In other words for a given subject and lighting a definite amount of light must be admitted and it is immaterial from the standpoint of exposure whether this be accomplished quickly through a large aperture or more slowly through a correspondingly smaller aperture. In computing exposure we can therefore concern ourselves first with the amount of light to be admitted as the main problem and then solve at our convenience the subordinate problem of the aperture and dependent time of exposure with reference to the needed depth of focus, stopping of motion or other considerations. The practical application of this method consists in the establishment of a series of numbers which are proportional to the net brilliancy or photographic powers of a series of subjects and which are obtained by dividing the appropriate U.S. stop number by the proper exposure time in seconds. By temporarily elimiating factors one, two, eight, nine and ten from consideration and combining the other factors it is possible for one gradually to build up in memory the results of accumulated experience in some such fashion as shown by the table below. The values given are those indicated roughly by the writer's experience; each worker will do best with a scale of his own making.

CONDITIONS	BRILLIANCY NUMBER	STOP-TIME COMBINATIONS
Bright sun Average landscape	200	U.S. 4 - 1/50 U.S. 8 - 1/25 U.S. 40 - 1/5 etc.
Bright sun Distant marine view, clouds	800	U.S. 16 - 1/50 etc.
Bright sun Near view of quarry face, 50 feet	50	U.S. 4 - 1/12 about U.S. 128 - 2 1/2 about
Dull light Shade, near view of outcrop, 10 feet	5	etc.

It will be apparent that it is vastly easier to remember a series of numbers such as 200, 50, 25, 10, etc., than to keep in mind the numerous combinations of stop and time which have been used in various equivalent situations. In the use of this system the results obtained in the fundamental scale can easily be modified for effects of latitude, film speed and filter according to theory or the operator's experience.

The use of exposure computors or meters along with such a mnemonic system will enable one to build up a memory scale more rapidly, to observe more closely the various values of the different factors and suggest modifications to the results given by the various devices under special conditions and interpretations peculiar to the operator. More complete data are contained in the American Photography Exposure tables which are of great value for occasional reference even if not used for every exposure.

At the outset it is very desirable to have an idea of the total arithmetical range represented by the various factors which affect exposure and the writer has attempted to indicate some of these in the table below. (Figure 9). The numbers given may be

TABLE SHOWING RANGE OF NOON ILLUMINATION FOR LATITUDE

Latitude	Relative Brilliancy	
	Summer	Winter
0 – 20	1	3/4
30	1	3/8
40	1/2	1/4
50	1/2	1/10
60	1/2	1/12

TABLE SHOWING RANGE OF BRIGHT SUN ILLUMINATION FOR TIME OF DAY LATITUDE 40°

Hour		Relative Brilliancy	
		Summer	Winter
12		1	1/2
11	1	1	1/2
10	2	1	3/8
9	3	3/4	1/4
8	4	1/2	1/16
7	5	1/2	1/32
6	6	1/4	
5	7	1/32	

advantageously used to modify the brilliancy numbers in expanding the table given above.

Filters vary in their required exposures from 2 to 30 times the normal according to the color and density. If we take the range of basic subject exposures as from 1 to 2000, that of the season and latitude factors as 1 to 12, of the time of day 1 to 32, of the filters 1 to 15, and of film speeds it will be apparent that the range in exposure required is very close to 1 to 12,000,000. If to this enormous range we add the effect of variation of apertures we find the possible theoretical range in exposure times is of the order of a billion fold.

When the amount of exposure needed has been estimated there remains the single problem of choosing a stop and thus determining the time of exposure. There are several possible governing considerations. If the exposure is to be made while holding the camera in the hand the exposure cannot safely be made longer than 1/25 second by most people. A few can, by standing very rigidly and holding the breath, make exposures of 1/10 second or more without blurring the picture but this should not be attempted until the operator has made a number of tests near to the laboratory to learn his individual limitations. The speed of moving objects, such as that of a breaking wave or of a tree swaying in the wind may determine the greatest permissible exposure time. If considerable depth of focus is needed for details of close objects or to bring a foreground in sharp focus it will be necessary to stop down to a small aperture. (Figure 2). The depth of focus obtained for different apertures and focal lengths is given in the table below. So many possible errors, some inherent in lenses and others inherent in the adjustments and nature of the subject, are eliminated or reduced by using time exposures and small apertures that the writer in common with many other geologists has found it advantageous to follow this practice with a large proportion of the pictures taken, including landscapes. To those who take great pride in the performance of a high grade anastigmat lens such advice may seem not to leave room for individual skill and craftmanship but it is the writer's belief that other aspects of photographic technique offer abundant opportunities for exercise of skill and that in the tremendously practical and necessarily secondary business of taking geologic photographs the chance of correcting many difficulties in one operation should not be ignored.

Among these are faulty estimates of distance, poor adjustments of camera parts, lenses inferior to the best, and depth in the subject. (Figure 8).

Making the Record

A record should be made at the time the picture is taken. This should include the approximate date, the location of the subject by state, by section or project and specifically on a map like any other geologic observation. A full title and statement of the import of the picture should be recorded. The photographic data such as time of exposure, aperture, time of day, conditions of lighting, etc. are not needed for the geologic record but are invaluable to one who is attempting to improve his percentage of good pictures. By inspecting and criticising the negatives when they are returned from the laboratory with the record of conditions in hand one's technique is improved more rapidly than by any method except that of developing the pictures immediately after they are taken.

Film should be developed as soon after exposure as possible since films deteriorate much more quickly after exposure than before. Under favorable climatic conditions films may be kept for several weeks without marked change but the practice is not good where other arrangements can be made, not only because of chance of spoiling but because of the desirability of knowing the quality of results while still in the field.

Tables

Many useful tables are contained in booklets of the Eastman and other camera makers and in photographic magazines. The following are presented as those most frequently used in the field.

TABLE OF HYPERFOCAL DISTANCES[1]

Focal Length	f/4.5	f/8	f/16	f/32	f/64
8″	250	141	70.4	35.2	17.6
6″	142	80	40	20	10.0
5″	99.5	56	28	14	7.0
4″	64	36	18	9	4.5
3″	37.5	21.1	10.6	5.3	2.6
2″	17.2	9.7	4.8	2.4	1.2

[1] The hyperfocal distance for a given aperture and focal length is that

DEPTH OF DEFINITION TABLE

Lenses commonly used on size	Distance focused on	f/4.5	f/16	f/64
3¼″ x 5½″	100	60′-inf.	32′-inf.	10′-inf.
	25	22′-28′	17′-52′	8′-inf.
	6	5 9/10′-6 1/10′	5½′-6¾′	4½′-10′
3¼″ x 4¼″	100	48′-inf.	21′-inf.	7½′-inf.
	25	20′-33′	13½′-inf.	6′-inf.
	6	5¾′-6⅓′	5′-7½′	3¾′-20′
2¼″ x 4¼″	100	35′-inf.	17′-inf.	6′-inf.
	25	18′-30′	11½′-inf.	5′-inf.
	6	5⅔′-6½′	4¾′-8¼′	3½′-inf.

beyond which all objects are in focus when the lens is focused at infinity. This table is computed on the basis of a circle of diffusion of 1/200 inch. Below the heavy line are allowable aperture — focal length combinations for sharp foreground with a camera levelled on level ground.

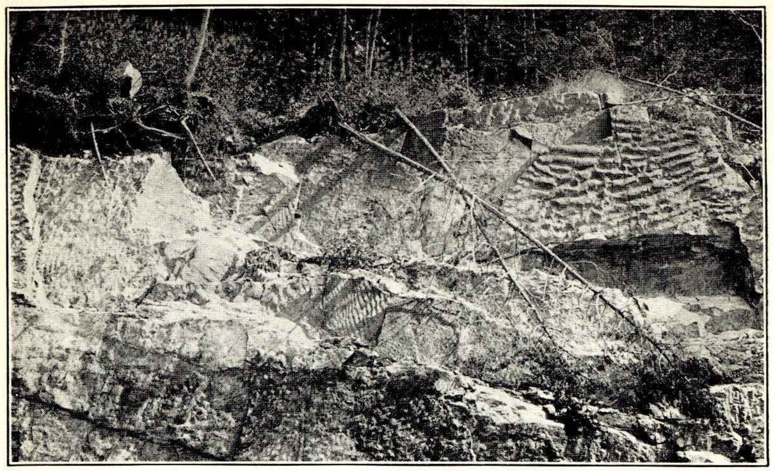

Fig. 1. Ripple marks on several bedding planes in Proterozoic quartzite. Baraboo Region, Wisconsin. An example of a photograph to be taken successfully with the sun in one limited position at a definite time of day.

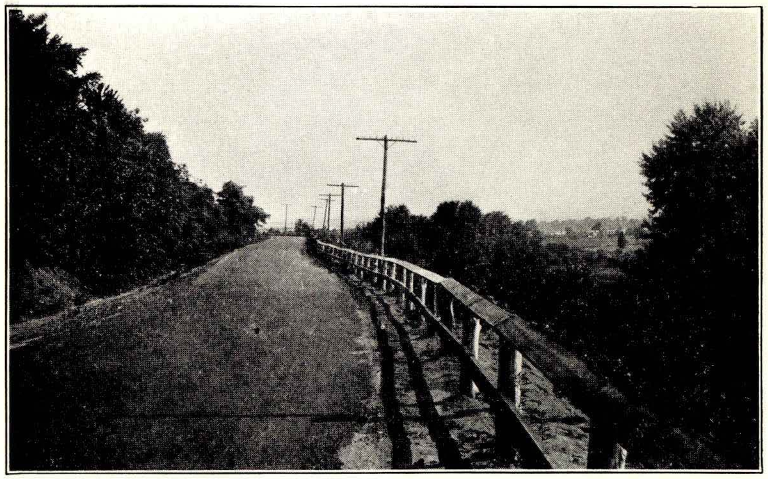

Fig. 2. View near Washington, D. C. Showing result of using small aperture to give depth of definition.

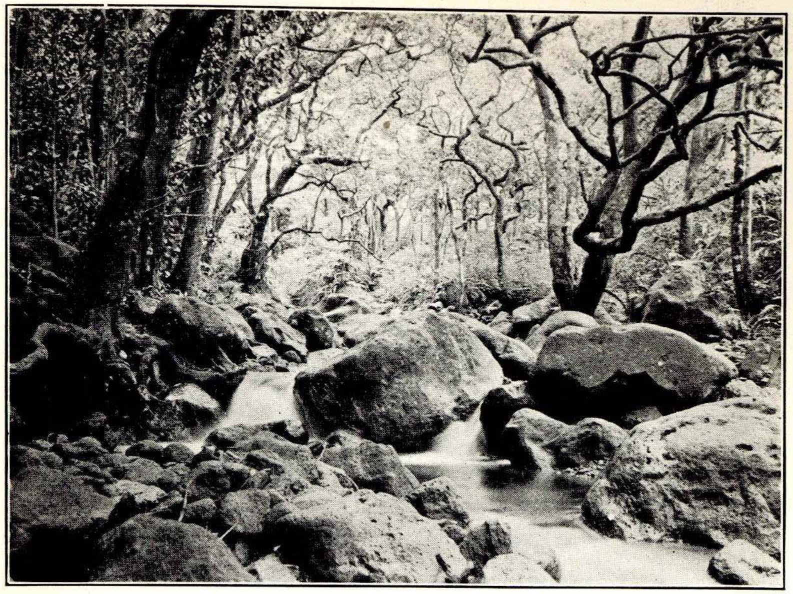

Fig. 3. View of channel of Mapulehu Stream, interior of East Molokai, Hawaii. A view requiring a small aperture for depth of definition even at the expense of sharpness in the moving water.

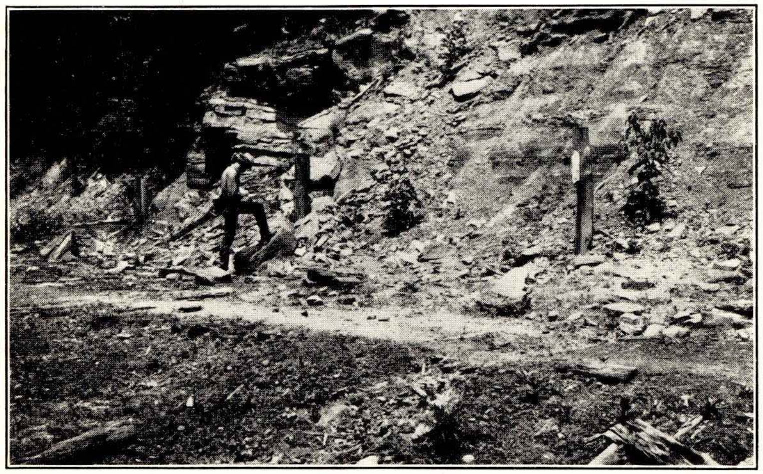

Fig. 4. Outcrop of Pennsylvanian coal measures near Dante, Virginia. An example of the unobtrusive use of the human figure as a scale.

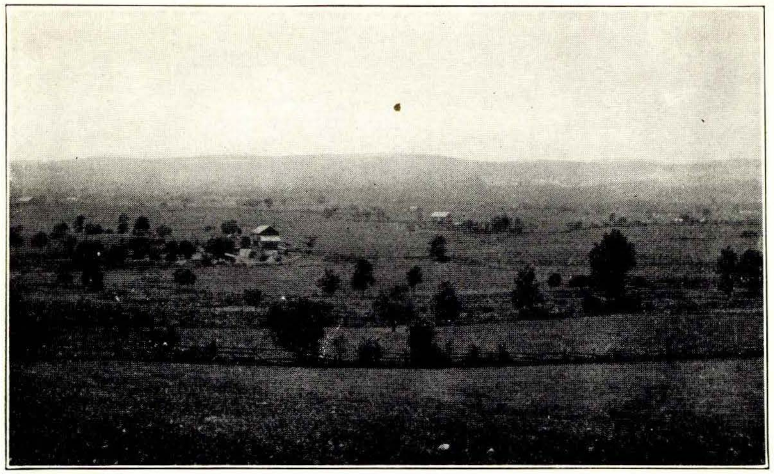

Fig. 5. View across Monocacy Valley in Maryland. Taken with portrait film and no filter. Detail is missing in the distant portions of the view. See Fig. 6.

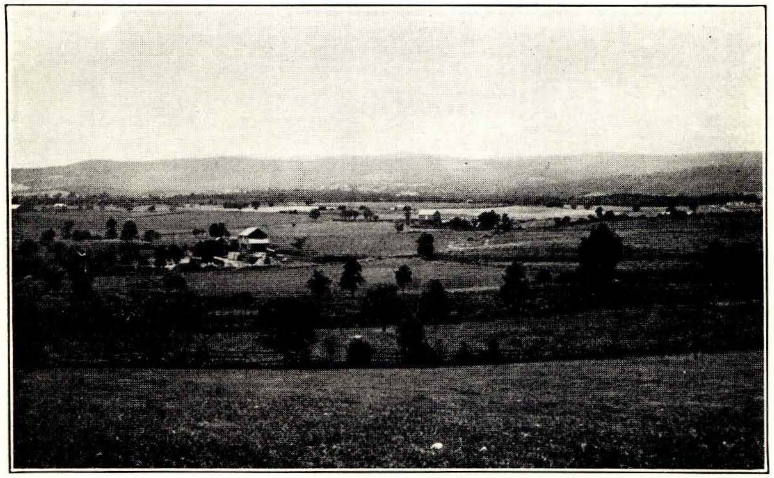

Fig. 6. Same view as Fig. 5. Taken with panchromatic film and deep red filter (F). The improvement in detail in the middle and distant parts of the view is apparent.

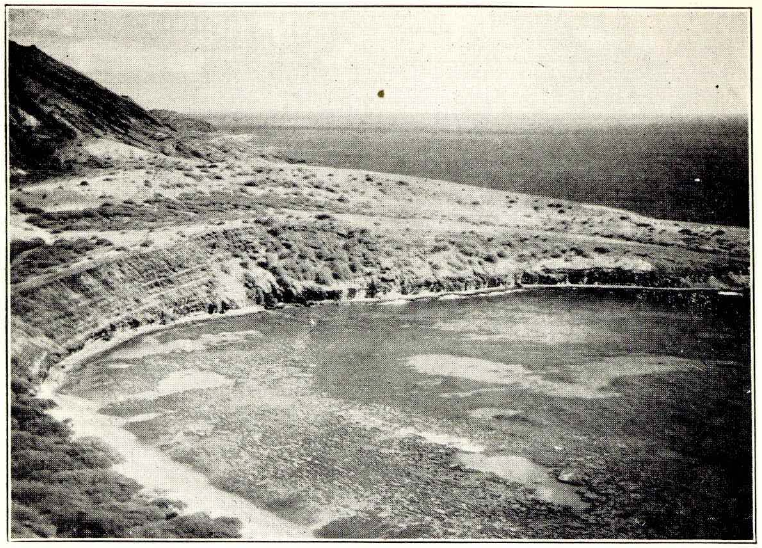

Fig. 7. View of Hanauma Bay, Koko Head region, Oahu, Hawaii. Taken with panchromatic film and orange (G) filter. The delineation of underwater reef detail over the entire area of the bay would be far less satisfactory without the filter and appropriate film.

Fig. 8. Detail of weathering of shale, near Norton, Virginia. Taken with auxiliary lens of portrait type. Example of satisfactory definition wrought over oblique field with a very imperfect optical system by means of very small aperture.

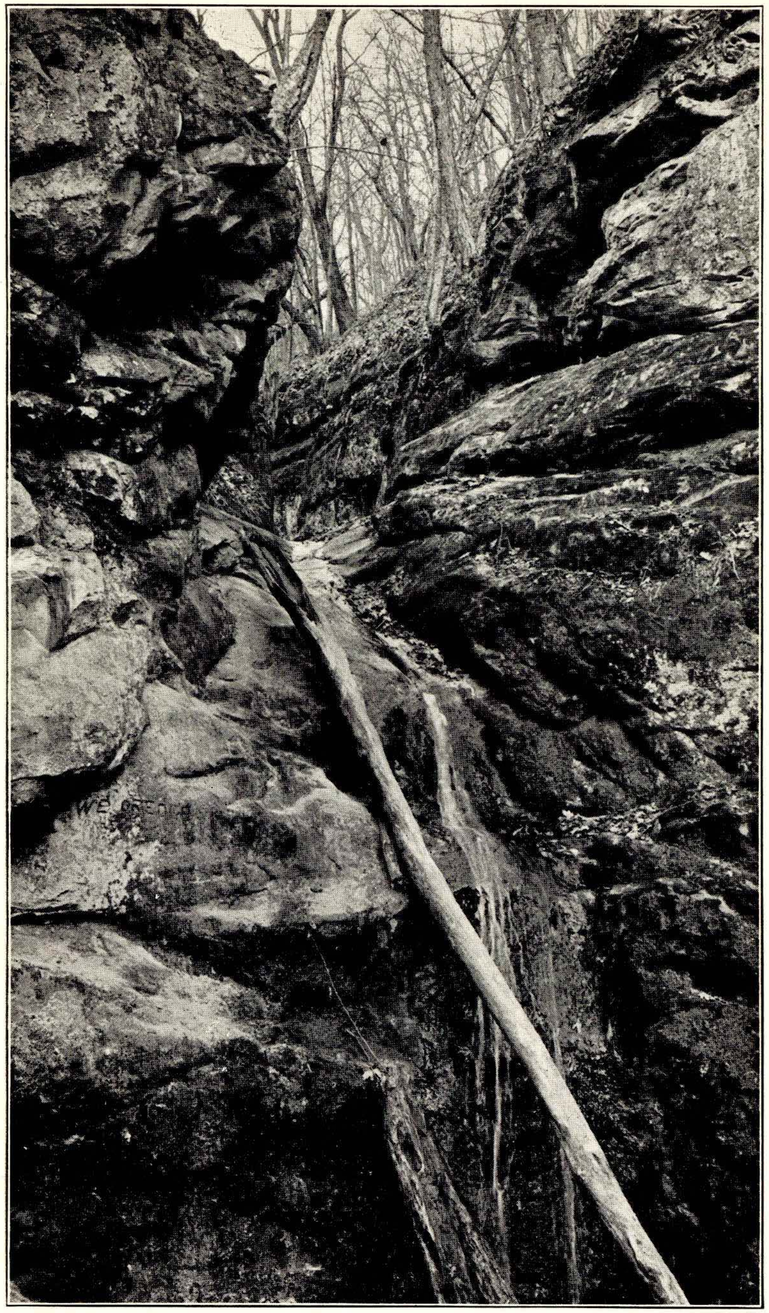

Fig. 9. View of fall in glen at Pictured Rocks, northeast Iowa. Taken at about 7:30 P. M. in late April in dark, shaded glen under trees. Exposure about ten minutes with f/32 aperture. Showing large increase in necessary exposure at late afternoon hours and satisfactory results if this condition is met.

THE DESERT STRIP OF WEST MOLOKAI[1]

CHESTER K. WENTWORTH
University of Iowa

INTRODUCTION

LOCATION

The west end of the island of Molokai is crossed by a strip of barren windswept country in which eolian features are developed with exceptional clarity and vigor. From a point on the north coast about seven miles east of the northwest cape this desert area extends in a southwesterly direction nearly to the west coast and has a length of about five miles and a width of about a half mile. Its location as well as other salient features of the island are shown in Figure 1.

GENERAL DESCRIPTION

The desert strip is due to persistent drifting of calcareous sand over the northwest upland by strong northeast trade winds. The sand is derived from two or three miles of sea beach at Moomomi on the north coast. Landward of this beach is a dune belt a half mile or more in width. The sand from the eastern end of this strip is not blown far inland but that from the western end is carried up a slope which averages about 10 percent or nearly 6 degrees to an elevation of over 600 feet and thence over the gradually declining upland for nearly three miles farther. (Figure 2). The writer visited the region at a time when the trade winds though persistent were of moderate strength and were moving a relatively small amount of sand. The testimony of observers who have crossed the strip during periods of strong wind emphasizes its activity as a transporting agent and the painfulness of attempting to face the flying particles of sand.

There is a nearly continuous cover of calcareous sand on that part of the strip which lies nearest the beach source and extending up well toward the highest part. Continuing in the direction of the wind the sand becomes less abundant and is confined to small

[1] Published by permission of the director of Bishop Museum.

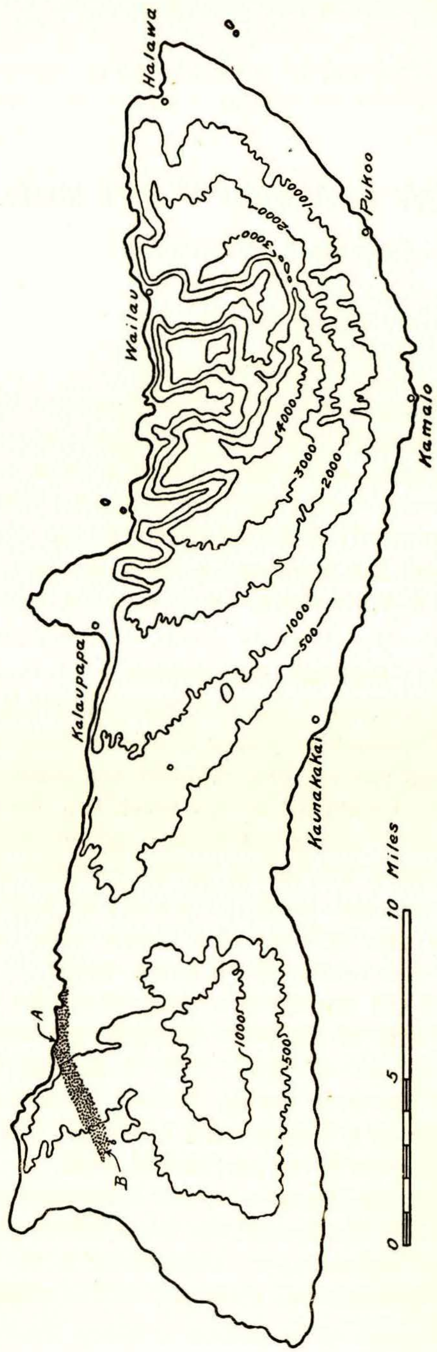

Fig. 1. Contour map of Molokai showing desert strip (stippled) on the west end. Topography shown by 500 foot contours on west end and by 1000 foot contours on east end, except that the 500 foot line is shown in the gap between east and west Molokai. Data from preliminary map, U. S. Geol. Survey.

dunes and linear ridges and to very subordinate quantities which lodge against and around occasional obstructions. At the southwest end of the strip there are extensive deposits of sand filling the heads of some of the smaller gulches and banked over the windward wall of Kakaako Gulch. At present this deep gulch constitutes an obstacle which the sand does not pass in appreciable amounts and no evidence was seen by the writer that it has been extensively blown to the far side at any time in the past.

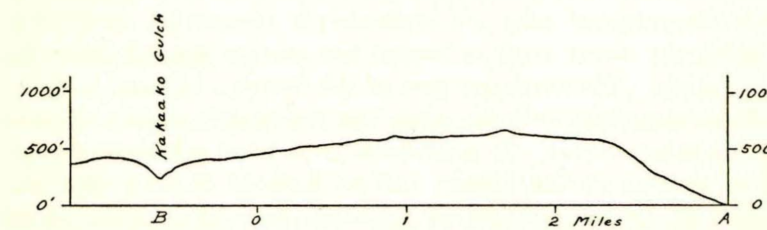

Fig. 2. Longitudinal section of the desert strip. Vertical scale exaggerated four times. See Fig. 1 for location.

Downstream from the end of the desert strip Kakaako Gulch is notable for the amount of fine sand which is incorporated in its alluvium and large quantities of the sand no doubt reach the sea at the mouth of this gulch. At the leeward end of the strip the sand is buff to brown in color and contains many grains of weathered basalt from the upland in addition to the fundamental organic constituents, but on the steep slope at the windward end the sand is whiter and more largely consists of debris from corals, algæ, molluscan shells and foraminifera.

In those parts of the desert which are not wholly covered with sand the surface is commonly abraded to a level from one to five or rarely ten feet below the original soil layer which is preserved in a few small boat-shaped remnants which are capped with sand mounds and rise to eight or ten feet above the eroded surface. Immediately below the old soil level the basaltic geest is deep red in color but becomes increasingly lighter colored with depth and at eight or ten feet is commonly a mottled yellow or orange and gray. Apparently wind abrasion becomes increasingly slow as it reaches the more resistent gray geest and it has at no place uncovered sound basalt in place. In a few places near the west end of the desert the surface consists largely of gray basaltic spheroids which have been uncovered by the wind and a few of these are isolated at other points.

Climate and Vegetation

The climate of Hawaii as a whole is characterized by low annual and daily temperature ranges, by the persistence of trade winds from the northeast and by the dependence of variations of rainfall on the local geographic factors of elevation and exposure to the prevailing winds. For the most part the southwestern and lower parts of the various islands are dry whereas the higher parts and especially those with northeast exposure have heavy rainfall.

No climatological data are available for the section of Molokai in which the desert strip is located but certain general estimates can be made. The northeast part of the desert is exposed to trade winds blowing from over the ocean and rises fairly steeply to more than six hundred feet. It is probable from what is known of rainfall at stations on the higher, eastern part of Molokai that the rainfall on the eastern end of the strip may be as great as 20 inches. The western end, which is lower and farther from the sea receives less rainfall, perhaps less than 10 inches.

The average hourly wind velocity is probably about 10 miles an hour. At times the velocity is very much greater than this, probably occasionally reaching 40 or 50 miles an hour. It is probably very rarely that the wind departs from the northeasterly direction indicated by the linear, parallel-sided form of the desert strip. Monthly mean temperatures of other localities on Molokai not far from the desert range from 68 in winter to 79 in summer and the mean annual temperature for the desert is believed to be about 72 degrees.

Practically no vegetation grows on the bare surface of the basaltic geest. Such plants as are present in the desert are those which grow on the overlying dunes and sand patches. None of these plants were collected but a few have been tentatively identified from sketches in the writer's notebook by Dr. Forest Brown of the Bishop Museum. These, the most abundant elements of a somewhat limited flora, were as follows:

Scævola lobelia
Lepturus repens
Ipomœa pes-capræ
Heliotropium curassavicum
Boerhaavia tetrandra
Xanthium strumarium

No materal was obtained which permitted the identification of the shrubs imperfectly preserved in the form of calcareous casts of roots and stems in some parts of the desert strip.

Acknowledgements

The writer is indebted to Mr. Fred Ohrt, to officers of Libby, McNeill and Libby, and to Mr. and Mrs. George Cooke for much assistance and many courtesies extended to him in the course of his studies of west and central Molokai. Without the hospitality with which he was met on all parts of Molokai it would have been impossible for him to have covered a considerable part of the island in the time available.

DESCRIPTION OF EOLIAN FEATURES

Larger Features of the Desert

Sand Formations. Three formations are to be distinguished by their physical condition. The oldest of these is a compactly cemented eolian sandstone which is found at a number of places along the margins of the present desert strip on both sides and extending the width of the eolian formations to at least a mile. This sandstone is buff colored on fresh surfaces and gray white on the weathered surfaces. It shows typical eolian bedding with curved planes mostly tangent below and truncated above. The surface of the formation is deeply weathered into pits and channels forming a deep cuspate profile with the sharp points and ridges pointing upward. This sandstone is considerably more abundant on the north side of the strip and forms together with some marine sandstones a great headland just west of the sandy beach on the coast.

The next younger formation is yellow to buff dune sand which is slightly cemented in places but is hardly to be called sandstone. This, likewise, is of typical eolian structure and lies in long oval mounds in close association with the modern sand dunes. These and the modern uncemented sand which is drifted and lodged here and there on the desert area constitute the third formation.

Dunes and Remnantal Sand Mounds. The commonest form of sand accumulation is that of an elongate mound of which the windward slope is somewhat less steep than that of the leeward side. The mounds are of all sizes from a few yards in length and ten feet high to several hundred yards long and 50 feet high. No well-marked crescentic dunes were seen. After accumulation has ceased the mounds, together with the underlying pedestal of geest, are subject to erosion and the windward slope then becomes steepest, the side slopes slightly less steep and the leeward slope most gentle of all. The relations of these sand mounds to the underlying surface are shown in Figure 3.

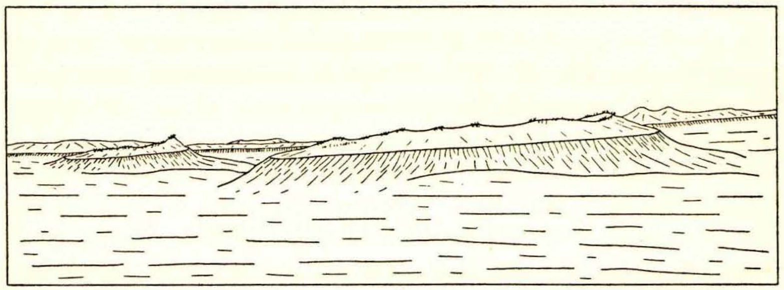

Fig. 3. Sketch showing erosion remnants of geest surmounted by sand mounds. Note the distinct line of the old surface between the two. View looking northwest, wind moves from right to left.

Leeward Crowding of Channels. At several points where the sand from the desert strip is drifting into gulches and small channels the windward side of the channels is almost completely covered with sand lying at the angle of rest of about 30 to 31 degrees. The leeward side, on the contrary, shows bare basalt walls and evidence that the ephemeral streams which flow in it are forced to the leeward side by the continuous infall of sand on the other side. There can be little doubt that over a period of many years this process results in a considerable shifting of the channel since the windward wall is largely protected both from abrasion and from surface weathering, while the leeward wall which faces to windward is subject both to stream and wind abrasion.

Dune Structures. The two most prominent types of structures in both the modern sand and the older eolian sandstones are talus bedding in which the beds dip at the angle of rest of about 31 degrees and what may be called whaleback structure. The latter consists of curving beds which lie parallel to the surfaces of the elongate oval mounds, being nearly horizontal at the crest and dipping increasingly outward toward the sides and similarly but less markedly toward the ends. This type of structure is seen

in many of the old masses of eolian sandstone and constitutes conclusive proof of eolian origin.

Desert Profiles. In looking transversely across the desert strip from either side one is impressed with the strong vector character of the profiles. This is especially true if the horizon itself is a part of the desert surface. The windward slopes of the elevations are steep or even eaten back so as to be overhanging. The leeward slopes are much more gentle and in general continue at a uniform angle down to the general level. It is to be noted that this relationship between steeper and gentler slopes is the reverse of that shown by most sand dunes in which the leeward slope of 30 to 33 degrees is the steeper. This difference is probably due to the presence of a slight vegetal cover or to a moderate amount of cementing in the mass which makes the windward part more resistant to the eroding wind than is the case with freshly deposited material.

Not infrequently the desert profiles are made more complicated by the presence of a distinct stratum of more resistant material, which is swept clean by the wind and caps the underlying mushroom-shaped pillars. These usually show clearly by their form the direction of the wind.

Striated Surfaces. Much of the desert surface is strongly striated and grooved. Except in a broad sense it cannot be said to be planed because there are many sharp irregularities on it and it thus differs somewhat from a striated glacial pavement. There are slight local variations in the direction of the striæ but they fall almost wholly between S 65 W and S 70 W. The character of the striated surface is well shown in Figure 4.

Tilted Blocks. None of the features of the desert is more striking than the tilted blocks which lie on its surface. These are most commonly discoid residuals of basalt which have been unearthed by the wind. As they lie on the surface they afford considerable protection to the underlying geest and come to stand on low elongate mounds of which the major portion extends to the leeward in the form of a lee prismoid as described below. During the long period of erosion from the time the upper surface is exposed until the blocks come to stand above the surrounding surface they are modified by the formation of a rain-pitted surface which is somewhat more nearly plane than the under surface and rather well separated from it around the annular rim of the discoid. As erosion continues the windward side of the elongate pillar is constantly undermined and in time the discoid becomes tilted forward toward the wind. In some instances the fall is violent enough so that the residual is displaced and rolls to some random position on one side but a large enough proportion of them assume a definitely oriented and tilted position to form a conspicuous element in the desert landscape.

After the discoid has fallen forward somewhat and lies with its pitted surface toward the wind it lies enough lower than it did before so that a small amount of material is deposited a little distance ahead of it and scour takes place immediately in front of, and behind it. See Figures 5 and 6.

Lee Prismoids. Closely related to the tilted blocks are the prismoidal pedestals which lie to the leeward. These taper to a point both in vertical and horizontal section and represent the form of least resistance to a moving fluid just as does the shape of most fishes or of properly constructed boats. The length is commonly three to four times the width and height, the latter two being commonly about equal. Similar prismoids which are usually much more closely controlled by the shape of the protecting stone are formed of sand behind small stones that lie on the surface.

Lag Materials. All over the surface of the desert one sees the effect of constant sorting by the wind and the resulting accumulation of lag materials which represent for the time and place too great a load for effective removal by the wind. Some of these fragments are large like the tilted blocks. Others consist of small angular and sub-rounded fragments of the weathered rock which accumulate in low or protected places on the surface. (Figure 7). These range from a centimeter or two in diameter down to those of sand sizes.

Chemical Deposits

Secondary Calcium Carbonate. In those parts of the desert which are scoured bare by the wind there are seen in the weathered basalt many calcareous joint fillings and nodular masses of calcium carbonate which have been deposited secondarily in the interstices of the basalt mass. The latter appear in some places to fill the spaces in old masses of basalt. Commonly these are somewhat more resistant to the wind than the basalt geest and stand above the surrounding surface as slight mounds.

Plant Moulds. It is impossible to tell how much of the lime in the above-mentioned joint fillings has come from the basalt in the process of weathering and how much from overlying masses of calcareous dune sand which have at one time or another occupied every part of the desert strip. At any rate in places which have been recently abandoned by the sand formations there are abundant moulds of plant stems and roots. These are commonly still standing with additional broken parts strewn over the surface. Not uncommonly the stem moulds stand above an old geest surface with parts of the sand formations still lying on it and the root moulds eroded at the margin of the geest surface and lying below it. In these places a few prostrate branches lie in place close to the geest surface and the moulds of what appear to have been extensive vine systems cover the same surface. These are merely rough external moulds of the plant parts and show no structure. The more compact, travertine-like part lies next the inner wall and the outer parts are more porous and carry loosely-cemented layers of the sand which formerly surrounded them. It appears that the cementing was achieved by waters carrying calcium bicarbonate which passed downward through the sand formations as they became stabilized and found the most favorable routes along the stems of plants. It is possible also that some chemical reaction between the decaying stems and the groundwater solutions favored deposition of the calcium carbonate. In places at least the calcium carbonate which appears in the superficial layers of the geest must have come from the leaching of the overlying sand formations.

Abrasion Features

Rock Striation. The striation of the geest surface has been described. In addition at various places in the desert strip but particularly toward the west end where rock fragments which retain a fixed position are more abundant the rock surfaces are distinctly striated by the action of the wind-drifted sand. The striation is best shown on the somewhat weathered surfaces of basaltic spheroids which are partly uncovered by the wind but are still in place and subject to persistent abrasion in one position. In such favorable situations a few rocks appear to have been cut away by abrasion to the extent of several millimeters or perhaps a centimeter or two. The resulting surfaces are rounded in a direction transverse to the wind but tend to be composed of straight line elements parallel to the wind and rising at angles of ten to twenty degrees toward the leeward. The striate character of the surfaces is fairly clear but differs from a glacially striated surface in that the whole surface is made up of fine groovings rather than of a planed surface marked with scratches. The direction of the individual striæ is subject to slight variation particularly where harder nodules or olivine crystals in the basalt project and deflect the wind currents. Similar results are produced by small pits and vesicles in the surface, from which the striæ radiate in a narrow spray or fan-shaped pattern. (Figure 8.)

Etching. Comparatively little differential abrasion or etching takes place in the basalt under the action of the wind because the rock for the most part is relatively uniform in hardness. In a few places olivine crystals are left protruding as the surrounding rock is worn away.

Polishing. A few of the pieces of dike rock which have been dropped by the Hawaiians are well smoothed and slightly polished but by far the largest part of the abraded surfaces are dull. It is probable that the minerals in the basalt are not favorable to receiving and retaining a bright polish. The fragments of secondary calcium carbonate which are found on some parts of the desert strip are moderately well polished and the sand itself is commonly composed of bright, smooth grains.

Windward Frosting. Some of the blocks of rock which are striated on the top and lateral sides show on their windward sides a rougher, lighter-colored and unstriated surface which may be described as frosted. This surface appears to be due to the impingement of grains of sand where the wind blows so directly against it that the sand is not deflected wholly around the sides or over the top to produce the striated type of surface.

Sand Blasted Pebbles. In a situation such as that being described one expects to find sand blasted pebbles but actually they are surprisingly rare. A few are found which bear the marks of considerable abrasion and have forms approaching to the two or three-angled sharp-crested einkanter, dreikanter, etc., which are found elsewhere. None of these has strongly carved facets or strikingly sharp edges.

Inferiority of Abrasion by Calcareous Sand. The abundance of features attributable to the blowing of the wind combined with the restriction of the marked effects to the weathered geest and to the superficial layers of harder parts of the basalt leads to the conclusion that the calcareous sand must be vastly inferior as an abrasive agent to the quartz sand which is common in most regions where wind abrasion is impressive. There would perhaps be little difference in the work of quartz and calcareous grains of the same shape on such material as the softer layers of the geest. On the harder rock fragments which lie on the desert there is little doubt that the calcareous sand is confined in its effects to moderate abrasion and slow polishing where quartz under similar vigorous wind action would achieve a much more vigorous carving of the rocks.

Discoid Shapes. Many of the larger basalt fragments which lie on the surface of the desert strip are the cores of units of spheroidal weathering. Some of these are nearly spherical but the bulk of them are oblately spheroidal or lenticular in form and show a considerable differentiation between the top and bottom surfaces. It is not to be understood that the cross section of these as viewed in the direction of the short axis is always circular. There is considerable variation but a strong tendency toward the typical form which is here described. The upper surface of the two is the least convex and is commonly pitted from the weathering which is favored by retention of rain water in initial hollows of the surface. In the most marked examples this pitting covers the entire upper surface, the pits being separated by relatively sharp crested rims. The lower surface is a convex one more nearly of the curvature of the annular profile and is developed on more deeply weathered basalt. On the upper surface the weathering is cleaner and the basalt more nearly fresh. Between the two surfaces is a more or less distinct annular rim which represents the surface of the ground at the time when the distinctive form was developed with the discoid block in a half-buried position. See Figure 5.

Surface Markings on Sand

Ripple Marks. Ripple marks are common on the tops and sides of the dunes and on the sand of the beach. Changes in the direction or strength of the wind commonly lead to alteration of the ripple marks, which as a consequence show the relics of one series being replaced by another. At one place were some large ripple marks of about a foot across, the crests of which had been planed off by the wind and made the site of a smaller series of marks.

Swing Marks. These are common in the sandy parts of the desert as they probably are in sandy regions in all parts of the world. So far as the writer knows no name has been applied to them and the name swing mark appears to be as good as any. They are formed by the swinging to and fro or round and round of stems or roots of plants which are anchored at one or both ends. The commonest form is produced by a grass stem which is broken over at the surface of the sand but not quite broken off. As this lies on the sand the wind sweeps it back and forth around the attachment pivot making marks on the sand in the form of a sector of a circle. If it swings through the full circle a target-like series of marks is the result. A more unusual form is produced when a slender, flexible root which is anchored at both ends is set in motion. This produces a shaded double convex lenticular pattern. See Figure 10.

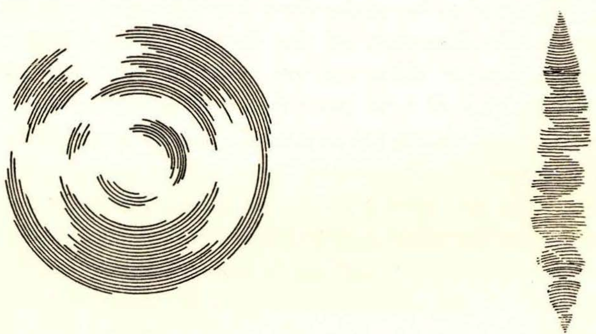

Fig. 10. Sketch of different forms of swing marks developed on sand by wind-swung stems and roots of vegetation.

Pebble Roll Marks. These are irregular discontinuous marks similar to those made by rolling a large snowball and are produced by the rolling of any small objects down steep slopes of the dunes.

Columnar Cliffs in Sand. These are produced by gravity sapping wherever the wind or any other agent has produced a vertical wall of a few inches or feet in sand which is wet or slightly cemented. The columnar configuration is produced by the faithful reproduction vertically of every irregularity in the lower part of the bank. At the bottom of such a columnar bank is commonly a series of merging talus cones made up of the material derived from the bank.

Tracks of Animals. Among the ephemeral features of the desert strip are the tracks of various animals. All those which are plain are in the sand since only the cattle and horses are heavy enough to make a recognizable track in the geest surface. The tracks of cattle were most abundant but those of horses, goats, cats, mice, birds, and various insects were noted.

Human Relics

Stone Implements. The ancient Hawaiians were skillful workers of stone and many evidences of their work may be found in the desert strip at the present time. The stone implements are not now so abundant as they once were but a few may still be collected. The most common implement is the adze which was made of very compact, fine-grained dike rock by chipping and rubbing. The bulk of those seen by the writer were blanks on which the larger part of the necessary chipping had been done but none of the rubbing. There is a close association between the adze blanks and all the other relics described in this section. They are found strewn over small areas of fifty or a hundred feet in diameter. Commonly they are close to the base of one of the low sand mounds which stand on remnants of the original geest surface. In a few places the relics lie on a geest surface and appear to have been covered with sand and then re-excavated by the wind. There is no convincing evidence however that the bulk of the Hawaiian relics were left on the desert strip at a time prior to the formation of the greater part of the modern sand dunes. It may well be that some were but the most of the material which lies about is probably not more than two or three hundred years old.

Far more abundant than the adzes and rough blanks are the chips and spalls which were produced in working them. These are identifiable both by their lithologic characters and the artificial shapes and freshness of some of their surfaces. It is possible that a few of the chips are from local rock of the discoid residuals but the majority come from a series of dikes near the coast north of the desert. There is a fairly distinct train of this material by which it may be traced back from the desert to the quarry from which the Hawaiians took it.

It is probable that the activity of the Hawaiian stone workers in this area extended over a period of many generations for some of the chips show at least two generations of etched surfaces. The first appears to have been developed on fragments of the adze rock which were dropped by the earlier carriers. Chips were then broken off these pieces as they were utilized by later generations for adzes. These chips are in turn etched by the wind-driven sand on the fresher faces. There is a distinct difference between the older and newer etched faces.

Marine Shells. Shells of pelecypods of various species and of several species of gastropod are scattered near the artifact materials. Most of these probably were used for food but there is one exception which furnishes clear evidence of human agency in transporting them from the sea coast. These are the cowrie shells (*Cypræa tigrina*) which are used as bait in squid fishing. These invariably have one side of the opening chipped out as is necessary to admit the straight stick which is inserted between the sinker proper and the shell.

Smoothing Pebbles. Small, very smooth pebbles, probably of beach origin in the first place, are used as smoothing stones in rubbing and polishing articles of wood and others were probably used in cooking small birds. All these are abundant round the artifact sites. In addition to these small pebbles there are a number of large beach cobbles of a somewhat elongate form and 20 to 40 centimeters in their longest diameter. These are rather symmetrical and were probably used for hammering and as anvils. (Figure 9).

Coral Files. A few fragments of rough coral which are shaped to a triangular wedge form are the files used in sharpening fish-hooks and in cutting away other materials. Near the various relics mentioned in a few places were found the remains of small fire places in which a few fragments of charcoal are still to be found.

HISTORY OF THE DESERT STRIP

Origin

The desert strip owes its existence to the action of the wind-driven sand in killing vegetation by abrasion and by burial. Though the west end of Molokai is dry and shows at various other localities the evidence of much work by the wind, the extreme development of strongly oriented eolian features is confined to the strip which extends in a straight line with well defined parallel sides across the upland. The sand is derived from the beach at Moomomi and is being formed today by wave action on the small living reef which lies off shore at this point. At the present time very little sand serves to keep vegetation down for the strip is now so deeply abraded that the exposed deeper geest is relatively unfavorable for plant growth.

History

Little is known which enables one to make an estimate of the age of the desert strip. The great mass of eolian sandstone which forms a headland just west of Moomomi beach was probably formed when the coast was less eroded and the land extended several hundred yards farther north than now since it could hardly have been formed by the blowing of sand from a beach having the location of the present one. The larger part of the old well-cemented sandstone on the upland lies to the north of the present strip and likewise suggests that sand had at an earlier time better access to the northern upland than now. Considering the amount of coastal abrasion which appears to have taken place and the cementing and weathering of the sandstone the origin of the desert strip may well be dated some tens of thousands of years ago.

At any rate it is clear that during the earlier part of its history it extended farther both to the north and also to lesser extent farther to the south than it does at present. Whether both of these greater extensions took place at the same time so that the desert was appreciably wider than now is not known but is thought to be probable. It is difficult to tell whether the desert strip was so long and continuous toward the southwest in the earlier part of its history as it now is because the southwest end of the desert once reclaimed would not carry as permanent marks of its old desert character because of the lesser quantity of sand which lies on it. Evidence of a broader desert strip are confined to the northeast slope and the summit portion and do not continue far to the southwest. With the abandonment of active sand drifting in the sections marginal to the present strip the desert assumed a regimen which was essentially that of today. Probably the earlier part of the history including the cementing, weathering and erosion of the oldest of the sand formations was very much longer than the later part during which the sand has been confined essentially to the present strip.

During this later period two fairly distinct formations of sand have been formed. So far as known only the latter is contemporaneous with Hawaiian occupation of the island. The locations of the fire places and other groups of relics are such as to suggest that the topography, even to the details of the sand mound remnants and tilted blocks, was substantially the same when the Hawaiians left them. The more recent activities of stone working Hawaiians are no more than 100 years in the past but the testimony of different stages in the etching of artifact chips is to the effect that the earlier Hawaiian work here may be several hundred or a thousand years old.

Importance of Wind Erosion

We may therefore conclude that the formation of some of the smaller features of the desert such as the sand-covered geest remnants or even the excavation and tilting of the tilted blocks may represent the work of several hundred years. The average amount of material removed by wind erosion in the desert was not ascertained with any degree of precision but by way of illustration we may take five feet as a reasonable figure. If the total age of the desert strip is estimated at 50,000 years this will amount to an average removal of one foot in 10,000 years. The principal value which attaches to a rough estimate of this sort which may well vary two or three fold either way from the truth is to indicate the relation of wind erosion under local and very favorable conditions to the rate of stream erosion. The figure given indicates that the rate of wind erosion may locally and under very favorable conditions approach the average rate of reduction of large continental masses by streams. The special conditions here with the continuous supply of sand which enters in no way into the computation of quantities removed must indicate the very slight quantitative importance of wind erosion in general as compared to stream erosion.

At the same time where conditions are relatively unfavorable to stream erosion wind erosion is capable of producing a large series of striking and typical topographic forms and details which quite dominate the landscape. At no place is this more strikingly shown than in one such as described above where strong trade winds blow persistently from one direction throughout the year.

Fig. 4. Detail of striated horizontal surface of the desert. Part shown is about two feet long. Direction of wind is from left to right.

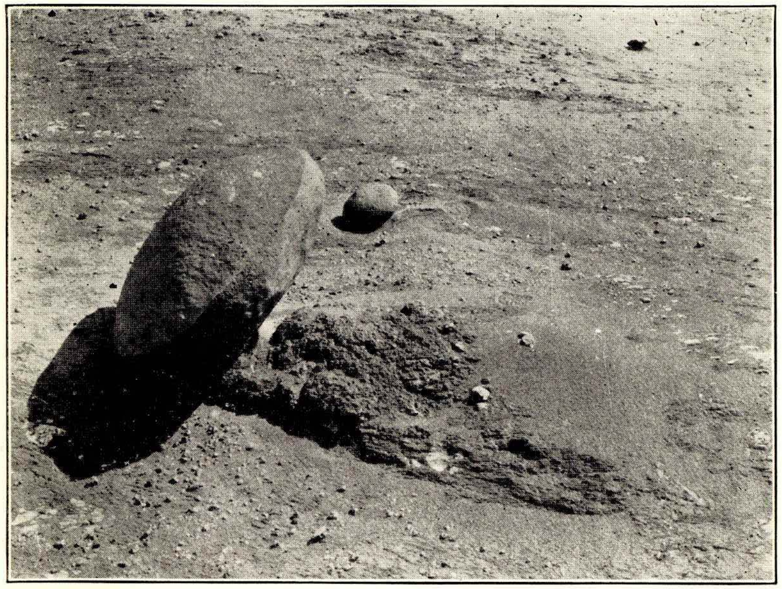

Fig. 5. View of tilted block showing discoid form and pronounced annular rim between upper and lower surfaces.

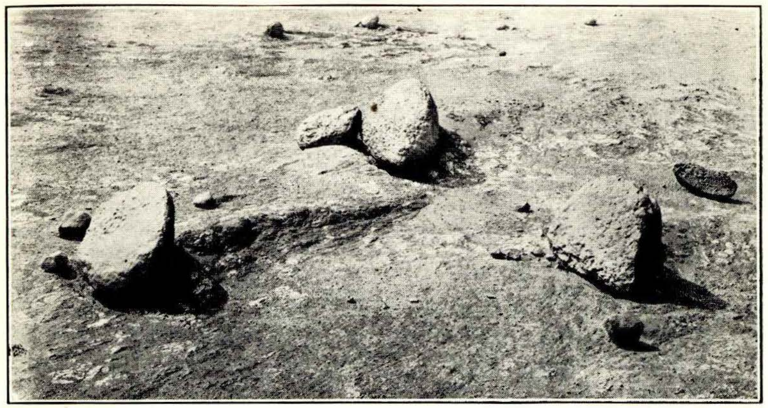

Fig. 6. View of tilted blocks showing rude discoid forms, pitted upper surfaces and elongate pedestals.

Fig. 7. Detail of desert surface showing cross section of spheroidal structure of basaltic geest which lies beneath. Loose fragments on the surface are loosened by plucking and uncovering by the wind and then become abraded and worn down to the harder stone.

Fig. 8. Detail of abraded and striated rock surfaces. Pencil points in direction wind moves.

Fig. 9. Detail of desert surface showing large rounded beach pebble and artifact chips left by Hawaiian natives.