DESERT FLOODS IN THE SONOYTA VALLEY.

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ABSTRACT.

Observed desert floods in the Sonoyta Valley, Sonora, Mexico, fall into three major types:—sheetfloods, stream floods and playa floods. Any or all of these may result from a single downpour, the type of flood being determined by the type of precipitation, the topography on which it falls, and the amount of precipitation on a given area in a given time. Definite storm paths were observed, and local convection currents, confined to the valley, or a part of it, were noted as important factors in secondary storms.

DESCRIPTION OF AREA.

The Sonoyta Valley is located in the northwestern corner of the District of Altar, state of Sonora, Mexico. The section of the valley in which these observations were made is that portion south and west of the town of Sonoyta, Sonora. The area is reached from Ajo, Arizona, by a fair desert road; from Nogales, Sonora, by a poor desert road; or from San Luis, Sonora, by a malpais and sand trail, which is frequently impassible.

The Sonoyta valley is the most westerly of a series of similar valleys which extends from a point east of Nogales, Sonora, to the Gulf of California. North of the Sonoyta valley are a number of other similar valleys, most of which are tributary to the Gila River.

The eastern edge of the valley, the divide between the Sonoyta and Arroyo Coyote drainages, is composed of the Sierra de Cubabi and related ranges, an enechelon (see Fig. 1) of fault-block ranges having an average elevation of 4,000 feet, and an extreme elevation of 6,200 feet, just south of the town of Sonoyta.

The western edge of the valley is less sharply defined, the divide, which separates the Sonoyta and Pozo Caballo drainages[1] being an indefinite line in the Pinacate lava beds, whose highest point, Pinacate Peak, 4,400 feet, is an erosion remnant of Santa Clara Volcano.[2] There is an underground drainage in the lava beds, whose outlet is unknown. The Pleistocene lava flows at Pinacate appear to have diverted the Sonoyta River, which apparently discharged at one time into the Gulf of California at Pozo Caballo, and now discharges

[1] Pozo Caballo is the deep embayment due west of Pinacate.

[2] Ives, R. L.: "Recent Vulcanism in Northwestern Mexico," Pan-American Geologist, Vol. LXIII, pp. 335-338, 1935.

into a series of playas, whose visible outflow seldom reaches tidewater.

The northern rim of the valley is composed of the Sierra de Agua Dulce, a granitic fault-block range; the cerritos at Quitovaquita (ten miles west of Sonoyta), and the Sierra de Sonoyta; both of volcanic origin.

On the south, the valley is open toward the Gulf of California, with a few volcanic cerritos projecting through the valley fill. The elevation of the valley floor at Sonoyta is 850 feet, and gradually decreases to sea level at the supposed mouth of the Sonoyta River, south of Adair Bay.

Each mountain range has a definite pediment, whose extent into the valley bears an apparent relation to the elevation of the range above the valley floor. For granitic ranges in this area, there appears to be about one-half mile of pediment for each thousand feet of average elevation of the range above the valley floor. Between pediments, in the center of the valley, the floor is composed of typical desert valley fill, overlain in some places by playa deposits, and in a few small areas to the west by recent lava flows. A narrow strip of dune sand, extending approximately twenty miles up the valley from the Gulf of California, suggests a marine transgression.

The upper Sonoyta valley, east of Sonoyta, drains into the Sonoyta River, whose channel is deeply eroded into bedrock at La Nariz, 20 miles east of the town. Just east of the town is a meadow, which is being channeled at the present time. Until about 1890, this meadow was a swamp, but in that year, a barrier of calcareous mineral-spring deposit was washed out, draining the swamp, and lowering the local water table. From Sonoyta to the southward bend in the river (Agua Dulce), the channel is cut to a depth of about twenty feet into valley fill, and has, in a few places, a rock bottom, erosion-smoothed, but not channeled. There is a wind gap at Agua Dulce, a short distance west of the present river channel, the bottom of the gap being roughly 50 feet above the river bottom. From Agua Dulce, the river has a shallow channel for a few miles, then divides into distributaries, which empty into a playa. South of the playa, there is an ill-defined channel, which, with playa-like gaps, extends to the Gulf. Hornaday[3] reports another playa southeast of Pinacate peak. Only during the annual summer rains is there any surface water in

[3] Hornaday, W. T.: "Campfires on Desert and Lava," p. 269, 1909.

the river channel south of Agua Dulce, and only on rare occasions is there any continuous surface flow in the river between Sonoyta and Agua Dulce. Underground water, fresh as far west as Agua Dulce, and saline from Agua Dulce to a point in the river bed east of Pinacate, is close to the surface, and can be obtained by digging a few feet in the river bed. At Agua Dulce, this water comes to the surface just east of a buried granite ridge (part of the pediment of the Sierra de Agua Dulce). In dry seasons it is saline and poisonous, and in moist seasons or soon after a river flood it is potable, although slightly bitter. Warm springs at Quitovaquita discharged into the river channel before the Papago inhabitants diverted the outflow for irrigation purposes. There are a number of other warm mineral springs in the valley, and a few good water holes, which, although of great importance to the traveller, have little significance in a study of desert flooding, and hence will not be described here.[4]

CLIMATE, INHABITANTS, AND BIOLOGIC FEATURES.

The climate of the Sonoyta valley is of the monsoon type, and is similar to that of the Tucson area, as described by Shreve.[5] There are two rainy periods annually, a winter rainy season characterized by gentle drizzling rains, and a summer rainy period, lasting from about August 15 to September 15, characterized by torrential rains on small areas. These summer rains produce the floods for which the Sonoran desert region is noted. Rainfall averages about eight inches annually, although certain limited areas receive a far greater amount.

The population of the Sonoyta valley, from the town of Sonoyta west to the Gulf, is something less than 1,000. More than half of this number are Mexicans, or Indians who have adopted Mexican culture. The remainder are Papago Indians, or members of the wandering Papago sub-tribe, the Areñeros. These inhabitants, a friendly, intelligent and hard-working group, make their living, and even some simple luxuries, by farming in this desert area.

[4] Accurate water maps in:—

Lumholtz, Carl, "New Trails in Mexico," map in pocket.
Hornaday, W. T., *Op. cit.*, pp. 23, 111, 1912.

[5] Shreve, Forrest: "Rainfall, Runoff, and Soil Moisture Under Desert Conditions," Annals-Amer. Assn. Geographers, Vol. XXIV, No. 3, pp. 131-156, 1934.

The plant and animal life of this region is typical of the Lower Sonoran life zone, amply described by Hornaday[6] and others. Except in a few areas, near permanent water, the cover of vegetation is so sparse that it has no appreciable influence on erosion.

CHARACTERISTICS OF THE FLOOD SEASON.

The summer flood season in the Sonoyta Valley begins about August 15, and continues until about September 15, with some relatively slight variations. Once in seven years, according to Mexican legends, there is an "Año seco," or dry year, during which there are no summer floods. Data collected in adjacent areas over a number of years do not support this legend. The flood season is preceded by about five weeks of extremely hot and dry weather, with local sand and dust storms, and shade temperatures as high as 125 degrees.

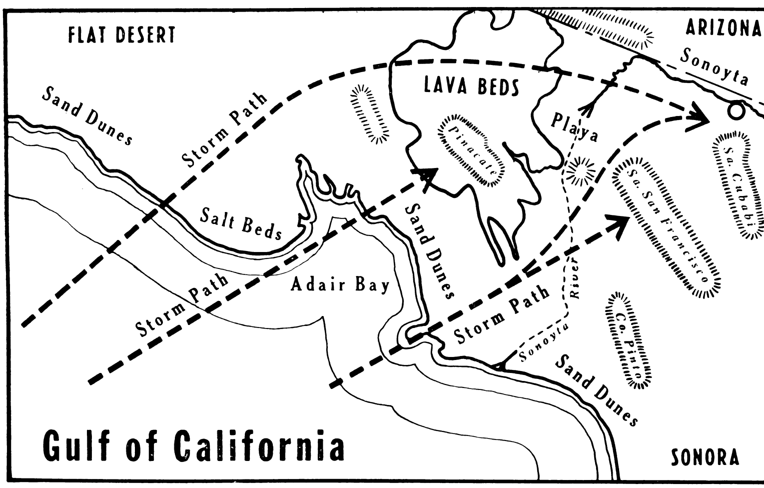

Fig. 1. Sketch map showing the major topographic features of the lower Sonoyta Valley, and the observed storm paths. The area included in this figure is 75 miles from east to west and 44 miles from north to south.

At the beginning of the flood season, clouds drive inland from the Pacific, drop much of their moisture in crossing the peninsula of Lower California, acquire a new moisture content

[6] Hornaday, W. T.: *Op. cit.*
Lumholtz, Carl: *Op. cit.*

while crossing the Gulf of California, and drift inland along rather definite paths, dropping their moisture when they approach a dominant mountain range. After dropping their moisture content, or a great part of it, the clouds leave the Sonoyta valley, going toward the Sierra Madre of Mexico, or northeastward into Arizona, still following rather definite paths.

A typical storm cloud will cross the peninsula of Lower California early in the morning, and by noon will be over the

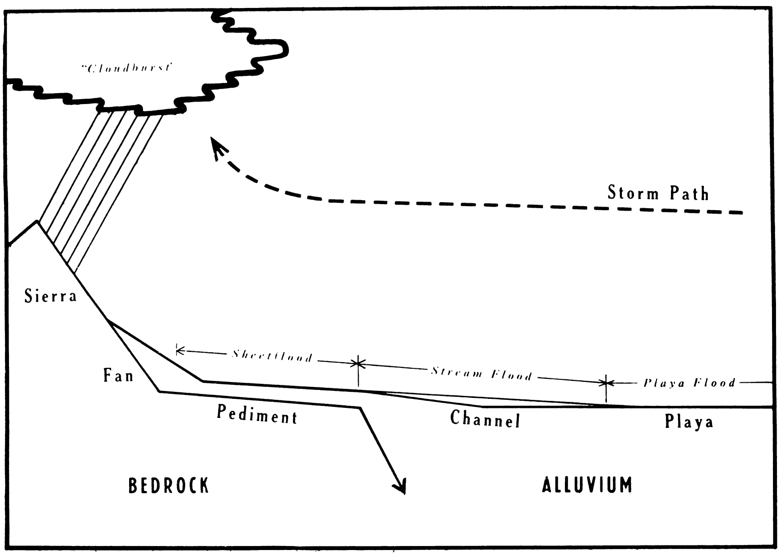

Fig. 2. Idealized cross-section of the eastern half of the Lower Sonoyta Valley, showing typical precipitation and type of runoff for a primary flood, with topographic relations.

Gulf. Here, it appears to pause, and become not only larger, but blacker in color. During the early afternoon, the cloud will again move eastward, following a course of approximately N. 30 E. for the first twenty miles over the Sonoran mainland, then following a line roughly parallel to the center of the valley. The velocity of a typical storm cloud in the valley is about twenty miles per hour. Near any of the dominant mountain ranges, a cloud will appear to stop moving forward, and will rise quite rapidly, probably being elevated by the valley-wall convection currents. When it reaches an elevation of between 6,000 and 8,000 feet, a cloudburst will occur, undoubtedly due to chilling. The runoff from this downpour, which almost invariably occurs directly over a sierra, becomes a *sheetflood* when it reaches the pediment of the range, a *stream flood* when it reaches the channeled valley fill, and a *playa flood* when it finally reaches the bottom of the valley. This type of flood, whose moisture comes from outside the Sonoyta valley, will be referred to as a *primary flood.*

After the primary flood, and often only a few hours after it, the playas fill with unabsorbed and unevaporated runoff. Soon after the playas are full, clouds form over them, and drift slowly toward the valley walls, following no well-defined paths, and dropping their moisture at almost any point within the valley. Occasionally, one of these playa-derived clouds will drift over the valley wall, and "escape" from the Sonoyta drainage. This cycle of rain, runoff, playa filling, evaporation, etc., continues for some time, until the water is absorbed, "escapes" or runs to the Gulf by underground, or in rare instances, surface channels. This secondary storm cycle will be referred to as *secondary flooding.*

DESCRIPTION OF PRIMARY FLOOD.

Primary floods in the Sonoyta valley were observed during the seasons of 1931 and 1933. The second primary flood of the 1931 season, being the most typical, will be briefly described.

Storm clouds were clustered about the northern end of the Sierra de Cubabi at sunrise, and thickened until about noon. The humidity was high, as was the temperature. At noon, a slight breeze was felt, and the air cleared. At the same time, intense flashes of lightning were seen on the sierra, and the thunder was deafening. After a few moments of these flashes, the lightning stopped, and rain was seen falling on the sierra. A few drops fell in the town, but the storm was centered over the sierra. About half an hour after the rain began to fall in the sierra, streams of water could be seen rushing out of gullies in the granite, and a roaring noise was audible in the town. The residents, used to this type of flood, had previously banked the adobe walls of their houses with earth. Water was soon seen rushing down the alluvial cones below the gullies, and the runoff spread into a sheetflood, similar to those described by McGee.[7] The front of the flood was about three inches thick, and after a few minutes, as the front was held back by friction, the water was a foot deep. One hour later, the water in the streets of the town was two feet deep.

The Sonoyta River just before the flood was about one foot deep. After 40 minutes of flooding, it was 30 feet deep, and still rising. During the latter part of the flood, the river was still deeper, but the river could not be observed.

Late in the afternoon, the precipitation ceased, and in the early evening, the water in the town subsided, leaving four inches of gravelly mud in its wake. The sediment dropped in the town area, which is at the junction of the pediment of the Sierra de Cubabi, and the valley fill, was composed of weathered granitic fragments, some fresh granite, and adobe mud, probably washed from the lower pediment. Clear weather the next morning permitted observation of the sierra, and a new gash, 1,000 feet long, and 50 feet wide and deep, was observed in the northwestern ridge. Large blocks of the granite removed from this gash were observed half a mile from it, and about 1200 feet down the slope. Overnight, the river had subsided from its maximum depth of more than thirty feet to about ten feet. By evening of the day after the flood, the river could be forded by a daring man.

Two days after the flood, the water at Agua Dulce, 20 miles downstream, was still shoulder-deep, and moving at a rate of about ten miles per hour. The major playa was full, and overflowing to the south. Haze made observations of the lower valley impossible for several days.

Water taken from the river 24 hours after the beginning of the flood precipitated one inch of fine silt in a glass in three hours, and was still turbid after four days of standing. A sample of flood water was centrifuged by Dr. Ross C. Whitman of the University of Colorado, and examined under a microscope. The sediment was composed of angular fragments of silica, and pointed fragments of black silica. The pointed fragments of black silica were undoubtedly volcanic glass.

Stream and playa floods were observed in 1933, from a point near Agua Dulce. From observations made in Sonoyta,

[7] McGee, W. J.: "Sheetflood Erosion," Bull. G. S. A., Vol. VIII, pp. 87-112, 1897.
Bryan, Kirk: "Erosion and Sedimentation in the Papago Country, Arizona," U. S. G. S. Bull. 730, pp. 19-90, 1923.

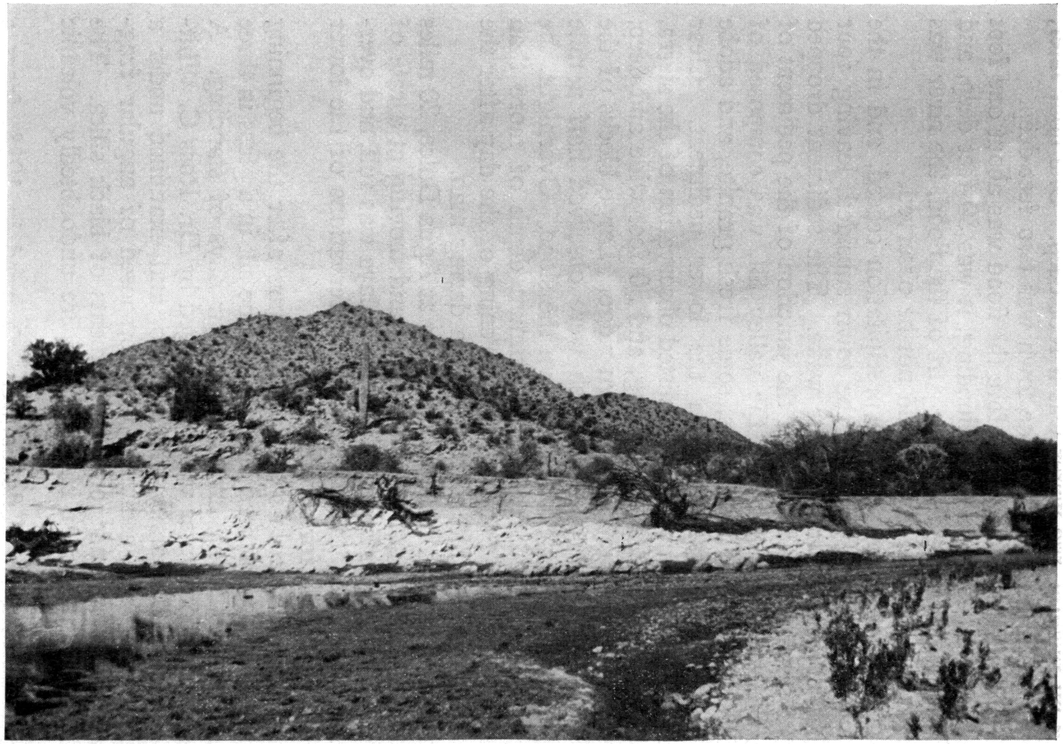

Fig. 3. Photograph at Agua Dulce just prior to a streamflood. Across the river can be seen the exposed pediment of the Cerrito de Agua Dulce (on the horizon).

it is certain that the precipitation causing these stream and playa floods was of the primary variety.

When camped on the second river terrace at Agua Dulce, a roaring noise was heard, coming from upstream. A photograph of the river bed was hurriedly taken, and the outfit, including a pot of boiling rice, was hurriedly carried to the high (third) terrace. A muddy wall of water rushed over the previous campsite, and roared down the channel. The front of this streamflood travelled at an estimated rate of 25 miles per hour, and was about six feet high. The "wall of water" was actually a complex curved surface whose shape was constantly changing. Carried along on the front of the flood was a mass of brush, and just behind the front was a desert tortoise, *Gopherus berlandieri*, swimming upstream with great vigor!

The flood was observed from a small hill nearby, and three miles below the campsite was seen to pass into the playa. The crest of the flood swept several thousand feet across the playa floor without visible spreading, then stopped its forward motion, and spread out over the playa, filling it in about 30 minutes. Later in the day, the playa was seen to be overflowing to the south, and the runoff disappeared in a bank of haze east of Pinacate Peaks.

This particular flood travelled the twenty miles from Sonoyta to Agua Dulce in 65 minutes, giving 18.5 miles per hour as its average speed. Mr. R. H. Bartlett, mining engineer, and long time resident of Sonoyta, reports that the average speed of a flood at Sonoyta is about 17 miles per hour. An Indian at Quitovaquita stated that the floods went past his camp (15 miles downstream from Sonoyta) "much faster than my horse can go."

During one of these primary floods, a tin can was set up as a rain gauge. When visited directly after the flood, the can, five inches deep, had overflowed! This does not indicate that there was a general precipitation of more than five inches during this flood, but only that in a limited area, where precipitation of this type is abnormally heavy, five inches of rain fell during one storm. During this same flood, and only a mile from the improvised rain gauge, the ground was hardly moistened.

Floods greatly resembling these primary floods of the Sonoyta valley have been observed in a number of nearby valleys, indicating that the same, or similar, forces cause them.

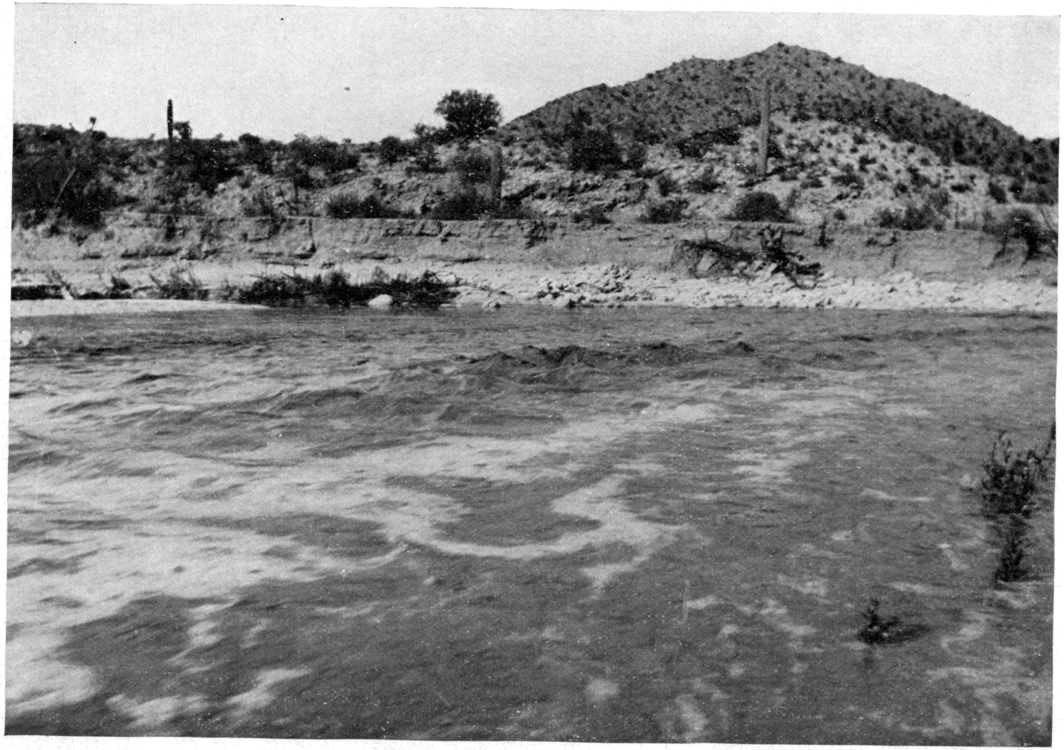

Fig. 4. Photograph at Agua Dulce a few minutes after Fig. 3 was taken. The transverse waves in the center of the figure are about 150 feet behind the front of the flood.

DESCRIPTIONS OF SECONDARY FLOODS.

Secondary floods were observed in the Sonoyta valley in both 1931 and 1933. When observed, the source of these storms was invariably a cloud which had its origin over the major playa. No definite paths for these storms were observed, and no definite center of precipitation is known. Apparently, these floods, whose moisture has its origin within the valley, continue until the playas are dry, at which time they cease from lack of water. One such flood, observed from Pinacate Peak, will be described.

About ten in the morning, a dark cloud was seen over the playa (northeast of the peak). Within an hour, it had visibly darkened, and soon started to move southward, at an estimated speed of eight miles per hour. After about fifteen minutes of southward motion, it veered to the west, and within an hour, was moving north over the lava beds. At about one in the afternoon, it stopped moving, and soon rain could be seen driving into a dry lake bed near the northeastern edge of the lava. Precipitation continued for about one hour, at the end of which the cloud had disappeared, and the playa was full. Two days later, this dry lake or playa was empty, and the bed was lined with rock-hard mud. While this was going on, several other secondary storm clouds formed, and during the day drifted away from the playa and precipitated their moisture. The secondary floods observed were never as violent or as lasting as the primary floods, and none of those observed took place in the sierra, although residents of Sonoyta say that this sometimes occurs.

PRECIPITATION AND RUNOFF.

A definite relation seems to exist between the type of precipitation, its location and the type of flood produced by it.

The mild winter rains in the Sonoyta valley sometimes produce streamfloods, and fill the playas, but seldom, if ever, produce sheetfloods. Winter floods, in general, throughout the southwest, are of lesser intensity than the summer floods.

The violent primary floods, which are almost invariably precipitated in the sierras, run off as sheetfloods in the pediment areas, streamfloods in the channeled valley fill, and end as playa floods. Rain falling directly on to a pediment seems never to produce a sheetflood, as it penetrates the thin veneer of alluvium, and forms a gravelly muck. From its very nature, a sheetflood cannot occur in a channeled area, and while a playa flood somewhat resembles a sheetflood, it seems unlikely that a sheetflood of any size can occur in a playa, due to the lack of gradient in the playa floor.

CONCLUSIONS.

The cycles of flooding can be observed in the Sonoyta valley: a primary cycle whose moisture has its origin outside of the valley, and a secondary cycle whose moisture source is the playa within the valley. The primary storms follow definite paths, and cause sheetfloods, streamfloods, and playa floods. The precipitation causing a primary flood is violent, and confined to a small area, upon which such a flood may occur each year. The secondary storms are erratic, less violent than the primary storms, and while causing, at times, the same types of flooding as the primary storms, more frequently cause only streamfloods and playa floods.

This report is based on reconnaissance observations, and, while every effort has been made to secure accuracy, is liable to the same errors as other reconnaissance work.

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