NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report No. 32-908

Sampling and Handling of Desert Soils

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ABSTRACT

Variability and characteristics of terrestrial soils and variability in methods and techniques used in sampling and handling are important factors responsible for discrepancies in results of investigations on soils. Procedures for soil sampling, as well as selection of the soil to be sampled, are usually determined by the purpose for which the soil will be used. Information is presented for the sequential selection, characterization, and sampling of a desert soil site. Procedures are recommended and illustrations given for photography of major features, sterilization of sampling equipment and sample containers, the collection of desert soils, and their handling, processing, storage, shipment, and dispersal. Aseptic technique is emphasized for the collection and handling of soil samples for microbiological studies.

I. INTRODUCTION

A. Soil Variability

Soil sampling is an important factor in various soil studies because most terrestrial soils are not homogeneous, nor are they simple systems. Except in a strict engineering sense, soils are not just unconsolidated masses of small-sized geologic materials in terms of their physical components. On this planet, soil is a three-dimensional body, usually a living system, which has developed in nature. Differences in the raw soil-forming materials and the natural environment have contributed, in time, to the development and formation of different kinds of soils.

Soils can vary on a point-to-point basis and from ecosystem to ecosystem insofar as they are developed and formed under the influence of complex and interacting forces of time (geological), climate, topography, biota, parent materials (minerals), elevation, and geographical position, as well as other factors (Refs. 1 and 2). Differences between various kinds of soils depend considerably on the intensity and degree of action and interaction of soil-forming factors. Variability in the interaction of these forces results in the development and formation of an immense number of soils on this planet.

Given the same soil-forming factors, the same kind of soil will be formed, whether it occurs at some location on this planet, or in some extraterrestrial environment. The same kind of soil will not be formed at a given location unless the same soil-forming factors are operative to the same degree. The less the interaction between factors and the lower the degree of intensity of each factor involved in soil formation, the lower the degree of complexity and maturity of the soil. Conversely, the opposite is also true. For example, a high interaction and intensity of climate (especially favorable moisture–temperature regime), and biota (especially dense, deep fibrous-rooted vegetation) will give rise to a high degree of soil development, and complexity, even though other factors of soil formation are similar to those of a less complex soil.

A number of methods have been used to sample soils and a variety of investigations have been performed on soils, but it has not been possible to devise a single method which is entirely preferable and satisfactory for sampling all kinds of soils at all times and in all locations. Shallow, rocky soils must be sampled, as well as dense, aggregated, cemented, and compacted soils, or soils composed of loose, cohesionless, drifting dunes. Sampling capability must extend to the dislodgment of *in situ* clays, silts, sands, and loams, as well as other larger geologic materials in various states of structural arrangements.

Productive soils, or those occurring in agricultural regions, usually have well-developed profiles of distinct A, B, C horizons and subhorizons, and these soils commonly show considerable variability in their characteristics with depth of soil profile. Desert soils may show much less variability of morphology or other characteristics with depth and are usually azonal, although hardpan or caliche layers may occur.

Whichever methods are selected and utilized to sample a soil, at least six factors must be considered: (1) characteristics of the environment external to a given body of soil; (2) soil-environmental relationships and interactions; (3) accessibility of the sample in terms of feasibility of procurement from the natural environment; (4) the variability, as well as the representative characteristics, of the sample; (5) the handling, processing, treatment, shipping, storage, and other conditions that will be imposed upon the soil after it has been removed from the natural environment; (6) the purpose for which the soil sample is required, i.e., the analyses and investigations which will be performed on the soil.

It is not always possible to satisfy all of the criteria for soil sampling, and some factors must receive priority over others. The soil should be considered in relation to its external environment. Knowledge of field conditions is essential to understanding the soil and its behavior. This also includes factors responsible for the development, formation, degree of maturity, and degradation of the soil, as well as comprehensive characteristics of the soil ecosystem.

Accessibility of the sample must be considered since it includes factors related to the best time for obtaining the sample and the time that must be spent in procuring the sample, location of the sampling site, depth and volume of sample required, design, bias and capability of the sampling devices, and transport and shipment of the sample from the site to another location, such as for analytical or experimental purposes.

For a given area and sampling site, variability of soil properties may be quite important. For example, an area of dune sand, or a broad, level, arid plain may show only a few soils with a narrow range of variability in soil properties. However, in a large area varying from a barren desert peneplain to wet, densely vegetated mountains of increasing elevation, and corresponding changes in climate, radiation fluxes, and different mineralogical composition, soils can vary widely from point to point, from ecosystem to ecosystem, and hence in individual properties of a single unit of soil.

Considering all of the factors in soil sampling, it has been found that the purpose and use for which the soil sample is required usually determines the kind of soil and the method of sampling (Ref. 3). The purpose also largely determines the quantity, quality, and depth of sample, the time of sampling, the number of samples, the selection of the area and choice of sampling sites, and subsequent procedures followed during the "lifetime" of the sample.

For most soil studies, it is desirable to collect a volume of soil, rather than an area of soil (Ref. 3). In most instances, this means that the investigator must obtain a soil unit which is a representative sample from a particular body of soil or soil ecosystem (Ref. 2). To ensure the collection of a representative and reasonably homogeneous soil sample, a number of dislodged samples or sample units are ordinarily collected from a body of soil. These samples are then mixed together, and an aliquot is taken as the representative sample of soil.

For some studies, a selective sample, such as from a specific area of soil or soil microenvironment, is procured. A selective sample, rather than a random sample, may also be desired, or even necessary, for some experimental design purposes, e.g., qualitative detection of soil microflora populations or other organics.

Procedures for collecting and handling of soil samples must be determined prior to actual procurement of samples in the field. In this respect, procedures for collection of soil samples for physical or chemical analyses are not the same as for procurement of samples for soil monoliths, or for microbiological analyses and research.

It should be realized that precautionary techniques for procurement of soil samples for microbiological investigations are not routinely utilized when obtaining soil samples. Methods for collection of soil samples in order to preclude contamination have not been well developed or tested. In this respect, it is quite difficult to obtain a quantity of soil from subsurface depths without introducing contamination from surface soil.

Procurement of worthwhile and scientifically valuable soil samples depends considerably upon the capabilities, preparation, and experience of the individual collector or investigator. Errors in soil sampling are increased by inadequate preparation, lack of sampling experience, lack of a rudimentary knowledge of basic soil principles and characteristics, poor choice of a sampling site, procurement of an insufficient quantity of sample, use of improper sampling methods and techniques, improper treatment, handling, storage, and shipment of the sample, inattention to the time of sampling with regard to environmental and soil conditions, and failure to take sufficient notes on characteristics of the sampling site, its environment, or other factors which influence the status of the collected sample. Errors due to sampling of soils are generally greater than those of soil analyses (Ref. 3), and these errors in sampling could affect the value of the soils for other purposes. As indicated above, any one factor or combination of factors can contribute to the collection of samples with decreased or very little scientific value. Sampling reliability must be emphasized at all times.

B. Historical Studies

Methodology of soil sample collection shows that most soils have been sampled for use in soil science or agronomy. Primarily, soil samples have been obtained for analytical purposes with reference to agriculture, and many subsequent examinations of soils have been undertaken by the various state and county agriculture experiment stations. According to one of the earliest accounts of soil sampling (Ref. 5), it was required that samples be procured from the "plow layer" or first 12 in. of soil. Samples taken from the immediate surface or less than 12 in. depth would not be considered for examination. It was also required that samples should not be randomly collected, but selected from distinct kinds of soils, and that they should be from nondisturbed or "uncontaminated" areas.

Before shipment or transport, the soil was to be separated from macrovegetation, and the samples were to be homogeneous from several representative sampling sites. Observed changes in soil characteristics with depth of soil were to be noted by the collector, and it was advised that cultivated, as well as adjacent virgin soils should be procured. It was also recommended that the occurrence of normal vegetation should be carefully noted and recorded, and that soil sites with unusual plants or vegetative growth should be avoided.

In arid areas, it was suggested that samples of alkali or salty soils should be collected toward the end of the dry season when surface layers contained the largest amounts of evaporated salts. All wet samples were to be air-dried before shipping or storing, and no soils were examined unless notes on soil location, lay of the land, soil "peculiarities," crop or vegetation, accompanied the sample. Otherwise, "the amount of labor involved [does not warrant] their examination" (Ref. 5).

Soil sample collection and handling procedures have evolved from the above requirements outlined by the first outstanding United States soil scientist, E. W. Hilgard (Ref. 5). Most of these principles for the collection and handling of soil samples have been retained to date. Although several modifications have been made for research purposes, most agricultural soils are still collected within 12 in. of the surface or from distinct horizons which compose the soil profile.

Little or no regard is usually given to slight contamination of successive layers or depths of soil by surface soil. No procedures are routinely followed for sterilization of digging tools, samplers, or sample containers. Aseptic techniques, except for specific microbiological purposes, are not used during the collecting and processing of soils, and this contributes to the contamination of samples by nonindigenous organisms and other materials. It is still standard practice to air-dry soils before shipping, storage, or determination of soil properties, but care is not ordinarily taken to exclude laboratory or open-air contamination of soil samples during the process of drying or other treatment. A time period of 24–48 hr or longer is commonly allowed to dry a soil. The soil may be exposed to open-air contamination for a longer time period, depending considerably upon the time and convenience for repackaging and for investigating the soil.

C. Purpose

Procedures for sampling and handling of soils are presented in this Report on the basis of procurement of manually dislodged samples of soil or sampling units which are to be removed from the field in a desert area. Instructions are intended for individuals who have had some experience in soil sampling, as well as for the inexperienced collector who lacks any background in soil science or in the procurement of soil samples from the field. Emphasis is given to procurement of desert soil samples of biological quality, and stress is given to the use of aseptic techniques which must be utilized in order to avoid sample contamination. The soil survey method of soil pit excavation and examination is utilized for obtaining large quantities of samples, and for the convenience of personnel in making soil depth measurements. The instructions are summarized and simple illustrations are given in Appendix A.

It is not the purpose of this Report to present basic characteristics of desert soils, various types of soil sampling devices and equipment, preparation of soil monoliths, or to suggest soil tests and analyses.[1] The subsequent methods and techniques presented in this Report are similar in some respects to soil sampling and handling procedures generally utilized by many soil scientists. However, the suggested procedures have evolved through experience gained in the aseptic collection and handling of hundreds of soils which have been analyzed for the JPL Desert Microflora Program.

Instructions are also included for those who may want to contribute to or obtain soils from the Desert Soil Collection at the Jet Propulsion Laboratory.[2] A typical Soil Sample Information Sheet and pictures of the corresponding soil site are included for this purpose in Appendix B. Additional information on standard practices of soil sampling, equipment for sampling, and characterization of the sampling site can be found in sections of some soil texts (Refs. 4–10). Useful information to observe and record at the soil site, and for a given depth of soil profile, are emphasized in a few works on soils (Refs. 11–13). Sources of error in sampling have been given by Cline (Ref. 3) and Petersen and Calvin (Ref. 14). Sampling of desert soils and their physical, chemical, and microbiological properties with reference to extraterrestrial life detectors and samplers have been presented previously (Ref. 15). It is assumed that the collector who intends to undertake soil sampling in a remote desert area will have made adequate preparation prior to his departure.

[1]Cameron, R. E., Blank, G. B., and Gensel, D. R., *Soil Tests, Measurements, and Properties*, JPL Technical Report, in preparation.

[2]Cameron, R. E., Blank, G. B., and Gensel, D. R., *Desert Soil Collection at the JPL Soil Science Laboratory*, JPL Technical Report, in preparation.

II. SELECTION AND CHARACTERIZATION OF AREA, SITE, AND SOIL

For soil studies in the JPL Desert Microflora Program, certain precautionary methods and techniques must be used for the collection, handling, processing, and storage of soils.[3] In this respect, older methods of soil sampling have been modified or replaced, especially with regard to the application of aseptic techniques and methods in order to exclude or minimize microbiological contamination for collection of surface, as well as depth samples of soil. The procedures given below have been developed through trial and error, and they have also been used successfully by individuals who have not had a background in soil science or who have not had previous experience in the collection of soils for microbiological research purposes.

A. Soil Unit

A soil sample is obtained from a larger portion of a soil body or ecosystem, and it is commonly referred to as a "sampling unit" (Ref. 3). The soil sampling unit is a quantity or volume of soil which has arbitrary limitations and dimensions for descriptive purposes, and it also possesses characteristics which can be defined or statistically estimated by sets of stable numbers (parameters).

The soil sampling unit is a useful working unit, and it can be used for various experimental design purposes and studies. It usually possesses some characteristics of the larger soil body from which it is procured. It, therefore, has some characteristics of a three-dimensional soil system in terms of area and volume, its physical, chemical, and microbiological systems, and solid (inorganic and organic), gas and/or liquid phases. A soil sampling unit is not the natural soil after it has been separated from the site, but a soil sampling unit is always a representative portion of the site, and the quantity, quality, and replication of this unit are usually a matter of choice, convenience, and purpose. A sufficient quantity of sample unit should be collected from the soil site insofar as possible.

B. Soil Area

The soil area refers to a broad exposure or expanse of soil, and associated rock, vegetation, topographic forms, and various other inclusive natural features. It includes a reasonable portion of the terrain which can be conveniently scrutinized, reasonably identified, and characterized by visual means.

The collector should allow a reasonable time period in order to "survey" the area before deciding whether or not it contains sites suitable for sampling. Some of the more conspicuous area features may indicate the density, distribution, and types of vegetation and animals, relative proportions of soil and rock, land forms, erosion and drainage features, direction of prevailing winds, slope of land, elevation, etc. The area should be traversed and observed to some extent, either by slow vehicle or on foot, before a final selection is made of the soil site. While examining the area, take care to avoid contaminating soils which may later be used for sampling.

C. Soil Site

The soil site is a working unit or subportion of the soil area or terrain which is suitable for soil sampling. It has three-dimensional characteristics which are convenient for sampling. For practical purposes, the soil site is arbitrarily delimited as the soil ecosystem. It should be accessible, as well as convenient for various personnel operations at the site.

It is important to check the site for evidences of contamination. Insofar as possible, a soil site is chosen which does not show contamination by humans, animals, vehicles, or trash. Evidences of contamination are footprints, disturbed vegetation, animal tracks, vehicle tracks, discarded bottles, cans, cigarette wrappers, expended ammunition cartridges, dung, feathers, anthills, rodent holes, etc.

Wherever possible, a site should be chosen which is not covered by, or adjacent to vegetation (trees, shrubs, bushes, grasses, remains of recent or partially decomposed plant debris, etc.). In deserts, small animals or evidences of small animals are commonly observed around shrubs which provide them with food, shelter, and protection from predators. An attempt should be made to choose a sampling site which is in an open expanse of bare soil, unless it is also desired to obtain samples from soil around vegetation and the corresponding rhizosphere.

Sampling sites should be avoided which are composed entirely of rock surfaces, but if there is no soil present

[3]Cameron, R. E., "Collection of Soils for the Program on Desert Microflora," August 1964.

in the area, then it may be desirable to dislodge and collect rock samples utilizing the same recommended aseptic procedures as those for collecting soils.

Following selection of the soil site, continue to take care not to contaminate it. Do not walk on the site! Sometimes the best sites in an area are contaminated while the area is being examined. Also be careful not to stir up dust, or disturb vegetation which may fall into the site, and do not deposit any collecting devices, instruments, sample sacks, wearing apparel, or other paraphernalia within the site.

At this time, measure and record any desirable microclimatic or soil properties, e.g., soil pH, oxidation–reduction potential (Eh), moisture, density, infiltration rate, reflectivity, soil color, temperature, and humidity.

D. Observations of Area, Site, and Soil

After the site has been selected, the area surrounding the site should be more carefully examined. These observations should be made as complete, objective, and clear as possible, and should be recorded in a notebook. Examine the general topography, as to whether it is mountainous, hilly, steep, gently rolling, flat, etc.

Note the erosion patterns (gully or sheet), degree of erosion (severe, moderate, or slight), and its probable source (wind, water, or both). Try to differentiate between natural erosion and accelerated erosion. Wind is a dominant gradational factor responsible for erosion in deserts, but for a relatively short time period, water can have tremendous erosional effects. Sudden deluges that occur in many desert areas provide turbulent, fast-running, debris-laden water coursing through drainage channels which eventually end in closed basins, temporary playa lakes (dry lakes), alluvial fans, or piedmont alluvial plains.

Landforms, while of significance in field geology, are also important features to note in the area in relation to the soil site and its development. Note the position, extent, arrangement, and composition of prominent natural features. Some of the features to note are flats, valleys, fans, terraces, mesas, buttes, hogbacks, spires, pinnacles, canyons, depressions and sink holes, isolated hills, remnants, dunes, sand washes, loess deposits, old beach deposits, lacustrine and marine deposits, cinder, ash or tuff deposits, lava flows, bedrock escarpments, glacial till or drift, steep or gentle mountains, scablands, badlands, etc. Attempt to characterize topography as to age in terms of conditions of development (not years, but whether it is young, mature, or old).

Badlands, for example, are complex, mature topographic forms which develop in many desert regions subject to deluges. Badlands are characterized by narrow, steep-sided valleys and narrow-crested hills, the entire area showing dissections by numerous gullies or arroyos and closely spaced valleys. Rocks that compose most badlands are alternating shales and sandstones, or predominately shales. Much of the Painted Desert in Arizona is a typical badlands desert region.

Vegetation, or the lack of it, is quite often characteristic of a particular desert region. Especially note the kinds or types of vegetation, e.g., xerophytic shrubs, cacti, short grasses, etc. Determine which kinds of vegetation are the most abundant or typical. Note the distribution of the various kinds of vegetation (scattered, irregular, or even), and the amount of vegetative growth (prolific, moderate, or scant).

Depending on the time of year, climate, local weather (especially as to favorable moisture–temperature conditions), as well as other factors, reproductive stages of some plants may be observed. If possible, make an estimate of the age and apparent health of the vegetation, e.g., dried grasses, new or dehiscent leaves, stunted, twisted shrubs, flaccid cacti, desiccated lichens, etc. Effects of fire can sometimes be noted, with evidences of charred wood, fire scars, second-growth, or revegetation.

As an example of desert vegetation, the creosotebush is the most widely distributed, the most evenly spaced, and the most frequently encountered, dominant macrovegetative form of the Sonoran Desert. It is also a transition plant found in surrounding deserts, such as the Mohave. The giant saguaro cactus is an example of an associative plant occurring with the creosotebush, but it is found on hillsides, in the Arizona Upland regions of the larger Sonoran Desert.

Observe and record past or present evidences of animals and the kinds of animals, e.g., cattle, rabbits, rodents, lizards, birds, etc., and their numbers and degree of activity. In addition to visual sightings of animals, record evidences of tracks, paths of travel, feeding remains, fresh or old bones, feathers, fresh or decomposed dung, and distribution and numbers of various kinds of burrows, etc.

Make notations as to the characteristics of soil(s) within the area, adjacent to the site, and especially within the site itself, where the samples will be collected. Pertinent observations to be made on soils in the field can be obtained by referring to any of the published

United States Department of Agriculture Soil Surveys, or the U.S.D.A. Soil Survey Manual (Ref. 7). Notations should be made as to the character of the soil slope or the incline of the soil surface and the microrelief.

In actual practice, soil slope is a consideration of the entire terrain. Soil slope characteristics are shape, length, and pattern of gradient. Slopes are either (1) single, or (2) slope complexes, as in a rolling terrain.

Microrelief or surface forms include desert pavement, desert varnish, fluffy or hard salt deposits, angular or smooth pebbles, large or small rocks or cobbles, lag gravels, loose or coherent sands, dispersed clay, shrinkage cracks, etc. Some desert soil surfaces are hard, dispersed, and compact, whereas others may be loose, dusty, lacking in cohesion, or possess a thin to thick fragile or dense crust.

Also, record any striking or unusual properties of the soil which may occur within the site, e.g., various kinds of salt layers, krotovinas, crusts, coatings, pockets, crystals, nodules, or concretions, conspicuous mineral deposits, sharp or irregular changes in color (mottlings), irregularities in structure, textural banding, stone lines, moisture variations, organic matter accumulations, etc.

Soil texture is sometimes estimated in the field by experienced personnel by the method of "feel" (Refs. 6, 7). Rub some of it between the fingers in both its wet and dry states. Notice whether the soil is coarse and single-grained, or very fine and coherent, loosely aggregated, powdery and fragile, or cloddy and hard to break apart. Look at some of the soil for fragments of organic matter, e.g., seed pods, dried grasses, dung, etc.

Try to evaluate the moisture status of the soil at various levels. Observe and feel whether or not the soil is wet, slightly damp, dry or very dry, and powdery or dusty. If a depth of desert soil is investigated, influxes or evidences of past precipitation can sometimes be observed as noticeably moist bands or layers of soil.

Most arid regions have red, grey, yellow, brown, salt or frozen desert soils. Within older classifications of desert soils these soils were included in Great Soils Groups of Polar soils, Tundra soils, Grey Desert soils, Sierozem, Brown soils, Reddish-Brown soils, Solonchak, Solonetz, Soloth, Lithosol, Regosol, and Alluvial soils. This classification scheme is still used by Soviet soil scientists and pedologists.

According to the more modern U. S. methods of soil classification, most desert soils fall within the categories and subcategories of entisols or aridisols (Ref. 11). Desert soils are hot or cold, and they are barren or formed under mixed xeric shrubs and bunch grass, or only scattered shrub vegetation. Available moisture is either lacking, low, or sometimes variable. Evaporation exceeds precipitation, except in polar regions where temperatures do not get above freezing.

Wind and deluge-type water erosion are definite developmental factors. Some desert soils are zonal, but most are very slightly weathered or leached and have either faint soil horizons and are intrazonal, or lack a profile and are therefore azonal or structureless. Many desert soils are found in large areas of barren, sandy or stony wastes, and many are shallow or frozen (permafrost) soils. Pans or cementations of calcium, sodium, iron, or silica occur in desert soils. Organic matter, organic carbon, and nitrogen concentrations are frequently very low; salts, soluble minerals and corresponding pH and Eh values may be high. Fertility may be high, but productivity is largely dependent upon quantity and quality of available moisture for a given time period.

Also make notations as to the meteorological and micrometeorological or microclimatic characteristics, even though these observations may be of a qualitative nature. Note the kind, amount, and distribution of cloud cover, e.g., few, thin, high cirrus clouds, the humidity, wind direction and estimated wind velocity, and temperature.

If instruments and time are available for these measurements, it is advisable to take readings for extended periods, and for a given profile or depth of environment. If possible, measurements should be made before, during, and after collection of the samples. Diurnal environmental measurements are preferable to those made at only one point in time. It is also extremely important to record information while at the sampling site. After departure from the site, it has been found that recall of pertinent information about the area, site, and *in situ* features of the soil are not reliable.

In addition to measurements of humidity, wind, and temperature, measurements can be made of evaporation rate; onset, amount, and duration of dew; solar radiation; net or total exchange of thermal radiation; occurrence and duration of sunshine; site elevation, and barometric pressure. Make any additional observations or measurements of interest. Too many notes are preferable to too few. Try not to overlook any special or unusual features in the environment which may have influence on formation and development of the soil and any of its physical, chemical and microbiological systems.

Reference to texts on deserts soil science, pedology, geology, botany, ecology, geography, and meteorology can provide useful information, especially with regard to features in the natural environment, and how to characterize them. Common words have become technical terms in various branches of science for the purpose of describing or measuring natural phenomena. Some common words have been given precise or unusual meanings. However, even without a familiarity with concise, technical terms and their meanings, a number of common words can be used in a qualitative sense in order to provide some information on the area, sampling site, *in situ* soil "profile," and the soil sampling unit.

III. PHOTOGRAPHY OF AREA, SITE, AND SOIL

Photographs are valuable in the characterization of the area, site and soil. In addition to the soil samples and recorded information about the area and sampling site, photographs are a valuable source of information. Photographs provide an excellent record of observable conditions and prominent features at the time of sampling. Pertinent photographs help to define, illustrate or contrast and compare one environment and sampling site with other environments and sampling sites. Pictures can also be useful in relocating the same site or similar areas for future sampling (Appendix B).[4]

Choose views which have a definite bearing on the subject Although the subject of the picture should be of scientific interest, the view should also be taken so as to obtain an artistic balance. Select definite features of interest, and hold the camera on a level so as to maintain balances of intersecting perpendicular and horizontal lines.

It is recommended that the collector should take two, or even three cameras if possible. One camera should be used for black and white film, the second for color negatives, and the third for color slides. Reflex or miniature cameras are often preferred, although movie and polaroid cameras can also be used. Whatever camera is used, the lens should have good to excellent definition (especially for close-up pictures).

Films are a matter of choice, although high-speed film is not necessary for most daytime desert photography because of high light intensity. Films are usually carried in tins or plastic sacks. They should be protected at all times from dust, extreme temperatures (especially heat), and moisture. After exposure, films should be marked and identified, and then developed as soon as possible.

Take too many pictures rather than too few, and make a record and notations as to where and when the pictures were taken. If necessary, also record the point of interest. Try several views, as exposures. Some views tell the story better than others. Consider shadows, the angle of incidence of the Sun's rays upon the soil surface, color and reflectivity of soil minerals, the microrelief, topography, and the time of day.

Take a minimum of two exposures of each view, and include at least the following: (1) pictures of the general area, including several hundred square meters of terrain, and also include the undisturbed soil site; (2) several pictures of the sampling site, including the exact location from which the soil will be collected; and (3) the same as Item (2) above, after the soil has been sampled, in order to show a cut or exposure of soil "profile" characteristics.

A fourth picture can be taken in order to show soil features from a much shorter distance. Other shots may be taken of any noticeable soil or associative property, e.g., caliche or mineral nodules, desert pavement, algal-lichen crusts, mottlings, fossils, roots, underground burrows, soil structure, moisture differences, etc. Additional pictures may include views of typical or unusual vegetation, geologic features, or of collecting operations.

A recognizable or known reference item should be included in the pictures, such as a man, meter stick, shovel, soil moisture tin, or soil site information sign. A soil site information sign is quite useful. This sign should include

[4]See footnote 2.

pertinent information and it should be used when taking a picture of the soil "profile" pit. Include on the sign the date and location of sampling, depth of soil, and soil sample identification numbers. The soil site information sign helps to associate areas and sampling sites with the soil samples that are collected. It has been found that unless photographs with proper identifications are made, it is possible to confuse similar areas and sampling sites. Sometimes areas and sampling sites are quite similar although in entirely different geographical regions.

Camera malfunction or scratched negatives are not uncommon in the desert. Dust is a primary source of trouble. This is because many desert regions are frequently windy, dusty, or are subject to dust and/or wind storms. Dust is sometimes stirred up through activities in the area, and especially at the soil site, and this dust seeps into instruments and equipment. Sometimes good distance pictures cannot be obtained because of interference from heat waves, haze, or atmospheric dust. A common rule is, don't overexpose the film in desert areas!

Operator ineptitude is also a cause of failure to obtain photographs, or else it is not always possible to tell when the pictures are good ones. Failure to obtain good pictures occurs either through unfamiliarity with the camera, improper choice of film, failure to consider contrasts of light and dark, failure to compensate for high light intensities, improper focus, dusty lens, as well as many other factors. If unfamiliar with the camera to be used on the field trip, then take pictures with a trial roll of film before the trip. After arrival at the sampling site is not the time to learn how to operate the camera. (This precaution also applies to any other equipment to be used on the trip, since spare parts are not available!) In too many instances, it is not practical to return to the area and sampling site in case the pictures were improperly taken, or were not obtained at all.

IV. STERILIZATION OF SAMPLING EQUIPMENT AND CONTAINERS

For the purpose of collecting soil samples suitable for microbiological research and analyses, it is necessary that certain sterilization procedures and aseptic techniques be used: (1) The preparation and use of sterile sample containers; (2) sterilization of samplers and/or digging tools; (3) the use of aseptic techniques to avoid contamination during procurement and dislodgment of the sample unit from the *in situ* soil; (4) the use of aseptic techniques during placement of dislodged samples into containers; and (5) precautionary measures to preclude contamination of the samples during subsequent handling, shipment, treatment, processing, and storage.

Sterile samplers (and digging tools) should be used for collecting purposes. In most cases, these samplers should be capable of being sterilized and re-used a number of times, e.g., metal shovels. In some instances, a sampler may be disposable and previously sterilized and packaged, e.g., various plastic items. If only a few samples are to be collected, and it is not desirable to carry sterilization equipment into the field, then small hand shovels or other small samplers can be sterilized in the laboratory prior to departure to the sampling site.

These items can be prepared in the laboratory by wrapping them in several layers of heavy aluminum foil, and then subjecting them to sterilization, either by heat, ethylene oxide gas mixtures, or other sterilants. It has been found that sterilization of small samplers can be achieved by autoclaving (120°C for 1–3 hours), or dry heat (180°C for 8–10 hr).

Ethylene oxide sterilization has been used successfully for both sample containers (plastic-lined canvas sacks) and metal samplers. Use 12% ethylene oxide/88% Ucon-12 for 24–48 hr at room temperature. If possible, sterilize the sampler, digging, or collecting devices and tools, e.g., shovel, pick, jack hammer blade, curved trowel, etc., while at the sampling site, and just prior to collection of the soil. If available, use a propane torch or camp stove for sterilization purposes. A propane torch and its fuel package are the most convenient to use, but a field oven or portable autoclave can also be used for small samplers.

If a camp stove is used, be sure that no carbon from partially combusted fuel accumulates on the sampler during the sterilization procedure. Also be certain to allow sufficient time for sterilized samplers to cool. (A hot shovel kills the microorganisms, alters the organic matter, and otherwise changes soil properties.) Avoid contamination of the samplers during the cooling period, and do not lay them on the soil unless it is the same kind of soil to be collected. (Discard the heated soil.) Re-use the heat-sterilizable samplers for successive collections of soil samples, and follow the same procedures as outlined above with regard to sterilization and cooling.

If no sterile equipment is available for sampling, then an alternate procedure can be followed, so as to reduce contamination. In this regard, be sure that there is no adherent material on the sampler from previous investigations. (Check especially for organics.) Also check for any material which may have accumulated on the sampling equipment during transport to the field. Rinse the sampler with the same kind of soil that is to be collected. This procedure involves shoving the sampler, e.g., shovel, vigorously into the soil, and taking care not to use this contaminated soil as part of the collected sample.

The rinsing procedure is also advisable for any sampler whether sterile or not. Rinsing can be recommended for faster cooling of the sampler following heat sterilization at the sampling site, and it also insures the removal or dilution and dispersion of air-borne microorganisms or dust particles which may have collected on a sampler during the cooling period.

V. SOIL SAMPLE COLLECTION

Prior to sample collection, check to be sure that all equipment necessary for sampling and packaging of samples is conveniently available and ready for use. Label the sample containers with appropriate information as to location of the sampling site (usually named after nearest geographical feature, town, etc.), date of sampling, depth of sample to be collected (approximately the surface 1 in., 1–6 in., 1 ft, 2 ft, 3 ft, etc.), sample number, and if desired, the collector's name. Include similar information, or at least the sample number, on soil moisture tins.

As a first step in sample procurement, collect the soil (the sampling unit) from approximately the surface 1 in. (2.5 cm), or from a shallower depth (indicate this depth on the sample container). In some cases, an easily dislodged soil surface crust can be obtained, such as salt crusts, "rain" or clay crusts, or algal or lichen crusts. However, in other instances, because of a pebbly or stony surface, this material must be removed (or it can be collected, if desired), before encountering the soil.

By means of the sterile sampler, fill the sample container as nearly full as practical, or is convenient to handle under most circumstances. It may be desirable to rinse the sample container with soil before filling it with the sample (discard this soil). Be sure to collect enough sample. It is much more preferable to collect too much sample rather than too little.

For most purposes, previously sterilized, strong, leakproof, plastic-lined, canvas, nylon-stitched sample sacks can be utilized satisfactorily. If samples are to be collected for the JPL Desert Microflora Program, sterile sacks, which will hold about 10 kg of soil, will be provided by JPL if sufficient prior notice is received from the collector. Fill the sacks with representative samples of soil from the same depth within the site. Do not pack the sack with soil. Be sure to leave some empty space in the sack if the soil is wet, because the increased pressure from swelling soil and microbial respiration can split the sack.

It is not necessary to homogenize or mix the sample in the sack, or to sieve it (unless this is desired). Mixing and sieving can be performed more satisfactorily during the processing of the soil samples in the laboratory where more time is available, and processing conditions can be more favorably controlled.

After the sack has been filled with soil, securely tie the neck of the sack with the drawstring, and be certain that the soil will not leak out during subsequent transport, shipment, and handling. (This is not only a precaution to exclude contamination of the sample, but it is also a requirement of the U.S.D.A. Plant Quarantine Bureau with regard to soil transport and shipping.) If the soil is to be shipped to the JPL Soil Science Laboratory, be sure to tie a JPL address tag to the neck of the sack. Several smaller sacks can be put into larger sacks, e.g., cement sacks or burlap bags, for shipping purposes.

At times, no sterile sacks may be available. Other sample containers, such as metal cans. can be utilized, and these containers can then be heat-sterilized at the sampling site. Rust-resistant containers are preferable to other kinds. Be certain that the sample container materials do not contribute contaminating material, e.g., preservant oil, factory dust, etc., to the collected soil sample. Bottles can be used, but are subject to breakage during rough handling, transport and shipment. Plastic containers, such as unreinforced, or unlined plastic sacks, unless of sufficient strength, are not usually satisfactory, and they tend to split at the seams.

When sterile containers are not used for the samples, then this should be duly noted on the container and in a notebook. If it is desired to decrease contamination of samples by nonsterile containers, then rinse the containers a number of times with the same kind of soil that will be collected. Indicate on the nonsterile sample container that it was "not sterile," and "rinsed." After collection of the samples, place them in a shaded or protected area, so as not to "bake" the soil in the Sun.

Following collection of the bulk of the soil sample unit from the surface, a second sample should then be taken with a standard soil moisture tin. If enough soil moisture tins are available, it is advisable to take more than one sample for averaging results. The samples taken with the soil moisture tins are intended primarily for soil moisture determinations. However, if this sample is properly taken, it can also be used to determine soil bulk density, and it will provide for a reasonable estimate of the void relationships or total porosity.

To take this sample, use either a soil moisture tin sampler, or if this is lacking, use the soil tin itself as a sampler. The procedure for taking the sample with the soil moisture tin is as follows: Place the open end of the tin on the soil surface, and gently force it into the soil with a rocking motion, so as to *completely* fill the tin, but do not compact the soil sample. Insert a shovel under the buried lip of the tin. If it is not possible to use this procedure to obtain a sample in the soil moisture tin, because of rocks or hard soil, then place dislodged material in the tin, and make note of this. (Although a soil moisture determination can be performed on this material, other procedures can be used to obtain values for bulk density and porosity.)

After careful inversion, and placing of the properly filled tin in the upright position, proceed to carefully scrape off excess soil which is above the lip of the tin. Also remove any soil particles adhering to the outside of the tin. Do not permit any organic matter, such as rootlets to hang over the lip of the tin. Finally, place the lid firmly on the soil moisture tin, and wrap several layers of moistureproof electrical tape securely and tightly around the interface between the lip of the filled tin and the lid.

Label and identify the tin with corresponding information or an identifying number which has already been written on the sample sack. A felt-tip marking pen with moisture-proof ink can be used for this purpose As was noted for samples collected in sacks, avoid placing any tins in direct sunlight or heat, because this may bake out moisture, stimulate microbial activity, or otherwise result in adverse positive pressure effects within the sample containers. If no other shade is available, place the samples in the shade of the transportation vehicle.

In order to obtain additional samples of soil at the site from lower depths of the soil "profile," remove successive layers of soil (Fig. 10), and repeat the procedures given above in regard to sterilization and cooling, sampling and labeling, etc. Additional precautions must be taken so as not to contaminate lower depths of soil with surface layers. If contamination should occur, remove any of the loose contaminating material, plus some of the contaminated *in situ* surface, and take soil samples only from a newly exposed and uncontaminated surface.

For the Desert Microflora Program, a second sampling unit is usually taken at a depth of approximately 1–6 in. (2.5–15 cm). A soil moisture tin sample is taken from the middle of this depth. For additional depth samples, again repeat the above procedures at approximately 1-ft (30-cm) intervals. Soil sampling units or soil moisture tin samples can also be taken from any other depths in the soil at which moisture or density differences may be noticeable.

Following the collection of soil samples, the recording of observations and measurements, the taking of photographs, and whatever other operations are necessary at the site, collect and check off all samples and equipment, etc., as was done at the beginning of the field trip. Remove all discarded materials from around the sampling site. Bury them at some distance from the site, or else discard them at the next public refuse collection container.

If a map is available, then try to pinpoint the location of the sampling site with reference to distances from described natural features, towns, marked highways, etc. If published geological topographic maps or soil survey maps are available, then use these, or else use highway, trail, or other maps. If published maps are lacking, then draw a sketch of the area and the sampling site, note a few prominent landmarks, and pinpoint the location of the site as clearly as possible.

VI. SOIL SAMPLE TRANSPORT AND SHIPMENT

Soil sample transport and shipment are important factors which are not always under the control of the collector. This is especially true when samples have been collected in remote locations, and must then be shipped via common carrier to the Laboratory. It should be noted that prior written authorization must be obtained from the U. S. Department of Agriculture Quarantine Division for import of foreign soils. State or local government agencies sometimes have additional regulations with regard to soil transport, shipment, and disposition of soil samples within or between states or counties.

If soil sample collections are made outside the continental U.S.A., a yellow S-37 soil importation authorization permit must be securely attached to each sample container of soil before shipment. For the Desert Microflora Program, prior permission has been obtained by the JPL Soil Science Laboratory from the U.S.D.A. Plant Quarantine Division to import soils from countries which have deserts. (A list of these countries and a copy of import regulations and the S-37 forms can be provided to collectors who intend to obtain soils outside of the continental U.S.A. for the JPL Desert Microflora Program.) Without a visible S-37 form, the U. S. Department of Agriculture is obligated to sterilize the samples whether soils or plant materials, following their arrival at a U. S. port of entry from a foreign country. The S-37 form must also be attached to samples arriving from the States of Hawaii and Alaska, as well as Puerto Rico, Virgin Islands, Guam, and other U. S. territories and possessions.

The Soil Science Laboratory at JPL should be notified if samples are not to be hand-carried to the Laboratory. Notification should be received as to when the samples were shipped, from where they were shipped, the method of shipment (air, ship, air-diplomatic pouch, etc.), the approximate weight of combined samples, the kind of containers, the number of individual packages of soil, or combinations of packages, and an estimate as to the probable length of shipping time.[5] The Soil Science Laboratory at JPL is also obligated to notify the Los Angeles County Agricultural Quarantine Bureau of shipment and arrival of soil, whether from outside the continental U.S.A. or from outside the State of California.

All possible precautions should be taken to prevent opening and off-site contamination of samples between their time of shipment and arrival at JPL (including sufficient time to notify JPL Shipping Department personnel that they are not to open the soil sample containers). If convenient, and in large quantity, send the soil samples collect via Railway Express, or by air if smaller quantities are collected

[5]If possible, telephone the JPL Soil Science Laboratory at Area Code 213-354-3339, Attention Dr. Roy Cameron, about soil shipment.

VII. SOIL SAMPLE HANDLING, PROCESSING, AND STORAGE

Sample handling and processing can be managed best by personnel in the Laboratory who will take precautionary measures depending upon the kind of soil, amount of sample, condition of the soil (whether wet or dry), and the types of analyses or other purposes for which the samples may be used. If the samples were air-dry when collected, then the bulk of the sample is retained in the original sample container. However, wet or damp soil samples are dried as soon as possible after their arrival at the JPL Soil Science Laboratory. Samples of soil in soil moisture tins are also dried immediately following their arrival at the Laboratory. Other samples, unless they must be inspected, transferred to another container, or mixed for various analytical purposes, are retained in the original sample containers until ready for use.

For drying purposes, wet or damp soil samples are spread by means of a sterile scoop in a thin layer (approximately 2 cm or less) on a tray covered with sterile, "heavy-duty" aluminum foil. Trays of soil are then placed in a closed drying chamber at room temperature, and exposed to a very gentle flow of filtered air. Following the air-drying of the soil samples, which usually takes several days, they are removed from the chamber, and repackaged, with mixing, under a hood. These samples are commonly repackaged into their original containers. Representative aliquots are then withdrawn from the sample containers for subsequent analyses or study purposes. Aseptic techniques are used at all times for the handling and processing of soils.

Aliquots of soil sample units are prepared primarily for four kinds of analyses: (1) physical, (2) physiochemical and mineralogical, (3) chemical, and (4) microbiological. These analyses require the preparation of either sieved or powdered soil samples. The processing of these samples is conducted under a hood, so as to reduce influxes and outfluxes of contamination. If available, a large, dry-box can also be used for processing of soil samples.

All of the samples are passed through a 2-mm (No. 10 mesh) sieve, unless the soil sample particles are already of less than 2-mm diameter. All of the soil sample material of 2-mm diameter or less constitute what is physically and chemically "soil" in terms of certain soil properties, e.g., particle size distribution, moisture holding ability, ion exchange capacity, etc. The fraction of material above 2 mm is sometimes retained for research purposes; otherwise it is discarded.

Materials for microbiological analyses (2 mm or less) receive additional careful treatment in order to eliminate or minimize contamination of a sample during handling and processing in the Laboratory. This includes the use of sterilizable sieves and scoops, and also sterile mortars and pestles if it is necessary to obtain a powdered specimen. Mortars and pestles are sterilized in an oven or by flaming. The sieves were designed and fabricated of stainless steel and the screens were silver-soldered and spot-welded to the sieve casings, so that they could withstand sterilization by the intense heat of a bunsen burner or propane torch.

The final processing procedure usually results in four aliquots of the soil sampling unit: (1) Coarse materials above 2-mm diameter, (2) material less than 2-mm diameter, (3) a separate, sterilized bottle of sieved soil intended for microbiological analyses and research, and (4) soil particles less than 2-mm diameter which have been subsequently powdered with mortar and pestle and are less than 105 microns (No. 150 mesh).

All soil samples are finally stored, either in the original plastic-lined, canvas sample sacks, which have been saved for that purpose, or are put into various sizes of screw-cap bottles. However, larger quantities of some soils are stored in previously sterilized metal barrels. All sample containers are closed, to exclude contaminants from laboratory air. Storage temperatures are commonly between 20 and 25°C. Barrels of soil are kept under a protective covering, and are, therefore, not directly exposed to heat from the Sun; otherwise, they are subject to ambient temperatures.

VIII. JPL SOIL SAMPLE DISPERSAL

A record of soil processing is kept at the JPL Soil Science Laboratory. This record includes information on the soil area and sampling site and the quantity and volume of samples obtained. A record is also kept on handling and processing of the soil, and as to whether or not aliquots of the soil sampling unit have been sieved and/or powdered. For certain purposes, soil samples collected primarily for the Desert Microflora Program and other bioscience programs at the Jet Propulsion Laboratory can be supplied to other individuals and agencies.

Information is kept on the name of the requestor, his organization or affiliation, his research needs, the kind of soil, quantity of soil, and its processing, and the date of removal of soil from the JPL Soil Science Laboratory.

Subject to approval by both the U. S. Department of Agriculture Plant Quarantine Division and the State of California Bureau of Plant Quaranti[illegible] soils can be removed from the JPL Soil Science Laboratory. However, removal of soils from this Laboratory is subject to their availability status and conditions imposed upon all laboratories working with soils in the State of California.

At the present time, the JPL Soil Science Laboratory, through NASA funds provided for the Desert Microflora Program, bears the cost of soil sample collection, transport, shipping, handling, processing, storage, and distribution of samples to other individuals or agencies. NASA-supported programs requiring soils for research or study purposes will be supplied insofar as possible on a priority basis. Reference numbers on soils and related geologic materials in the Desert Soil Collection will not be changed, and therefore, can be used to identify soils obtained from the Laboratory whenever reporting results of analyses or studies on these soils. Upon near exhaustion of a given sample of soil, the remaining sample (approximately 100 g) will be retained as a museum specimen.

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APPENDIX A

Sequence of Steps for Collecting Soil Samples in Desert Areas

1. Check vehicle, equipment and supplies prior to departure to the field (Fig. A-1).
2. "Survey" suitable areas for possible sampling sites (Figs. A-2 and A-3).
3. Take photos of the area, and make notes on observations (see Appendix B; Figs. B-1–B-5).
4. Inspect and select suitable soil site. Take additional photos of pertinent area and site features, and record observations (Fig. A-3).
5. Make pertinent environmental and *in situ* soil observations and measurements (Figs. A-4–A-9).
6. Prepare and arrange equipment for soil sampling operations (Figs. A-1, A-10, and A-11).
7. Make sign for identification purposes (Fig. A-12).
8. Sterilize and cool/rinse soil samplers, digging devices, etc. (Fig. A-10). Adequately label soil sample containers (Fig. A-11).
9. Collect soil surface samples from depth of a few cm (Fig. A-12).
10. Collect corresponding soil moisture tin samples (Figs. A-10, A-13, and A-14). Be sure that all soil moisture tin samples are adequately packaged and labeled (Fig. A-11).
11. Repeat sterilization, cooling, and sampling procedures, so as to obtain soil sample units from deeper depths of soil "profile." Take samples from levels of 1–6 in., 1 ft, 2 ft, 3 ft, but not more than 3 ft in depth, unless otherwise desired (Fig. A-12). Do not contaminate deeper layers of soil with surface materials.
12. Store collected samples in protected area, e.g., under vehicle, away from direct sunlight and heat.
13. Following the collection of soil samples, take additional photos of the sampling site showing exposed soil "profile" and vertically placed meter stick and identification sign in position (Fig. A-12).
14. Make final notes, and indicate location of sampling site on map (Fig. A-15).
15. Collect and check all samples and equipment (Fig. A-1). Leave the area and sampling site in as good condition as possible, and remove all discarded materials, trash, etc.
16. Attach address labels, and also import form, if necessary (Fig. A-16). Transport and ship soil samples to the Laboratory. Notify pertinent Agencies and personnel in regard to shipment of samples.

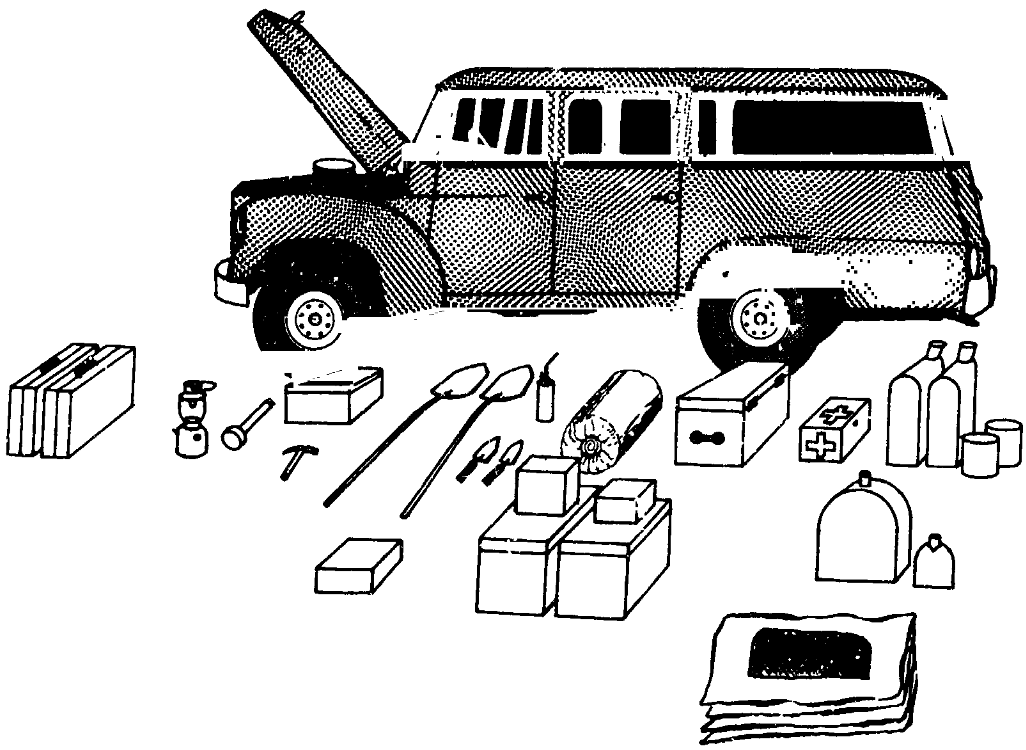

Fig. A-1. Four-wheel drive vehicle and miscellaneous field equipment laid out for inspection prior to departure to desert areas

Fig. A-2. Preliminary "survey" of a desert area and sighting of possible soil sampling site

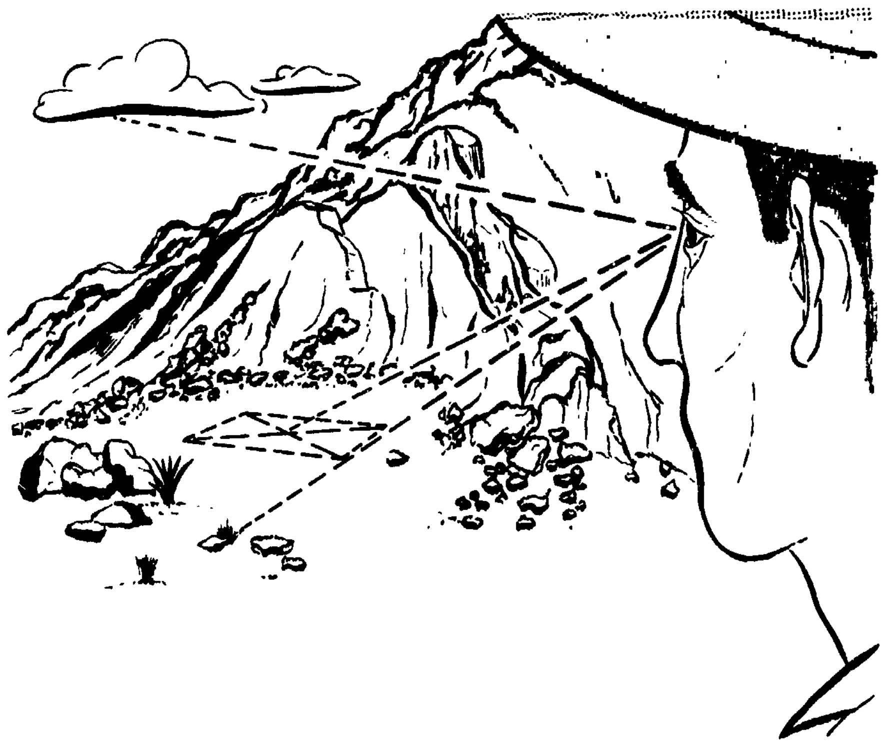

Fig. A-3. Inspection and selection of soil sampling site, observations of meteorological conditions, scattered vegetation, and other natural features

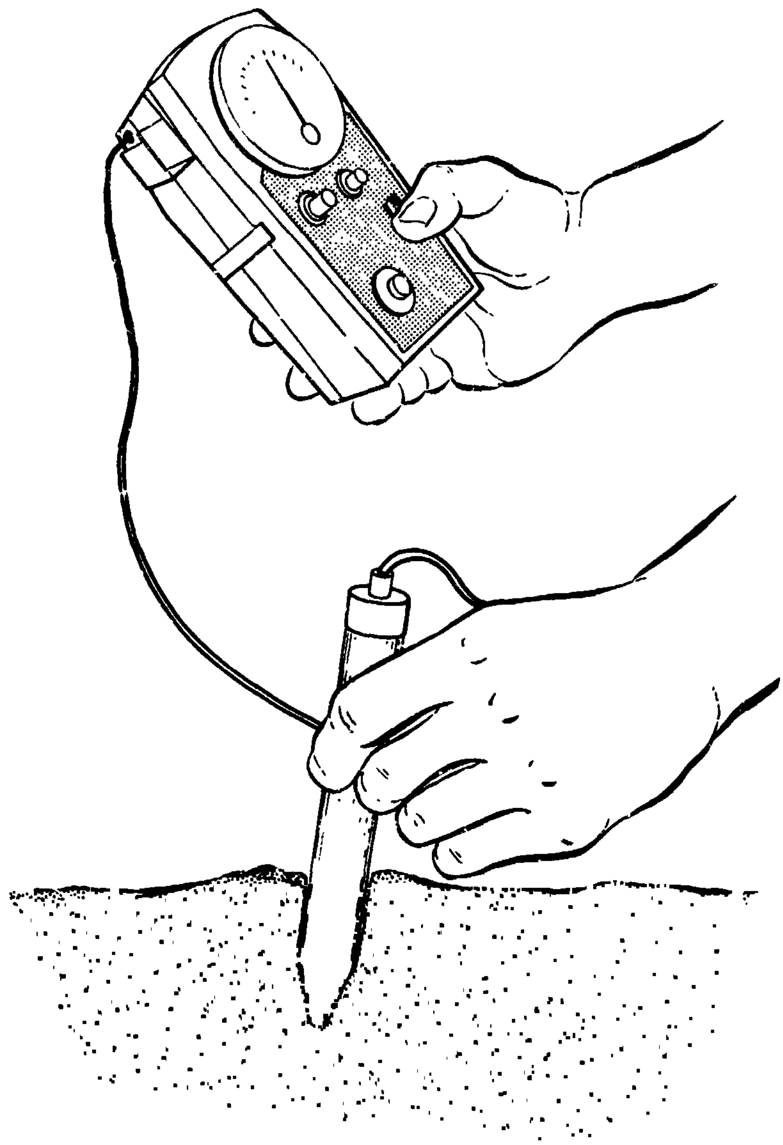

Fig. A-4. Portable pH meter with hard-glass combination electrode for measuring *in situ* soil reaction

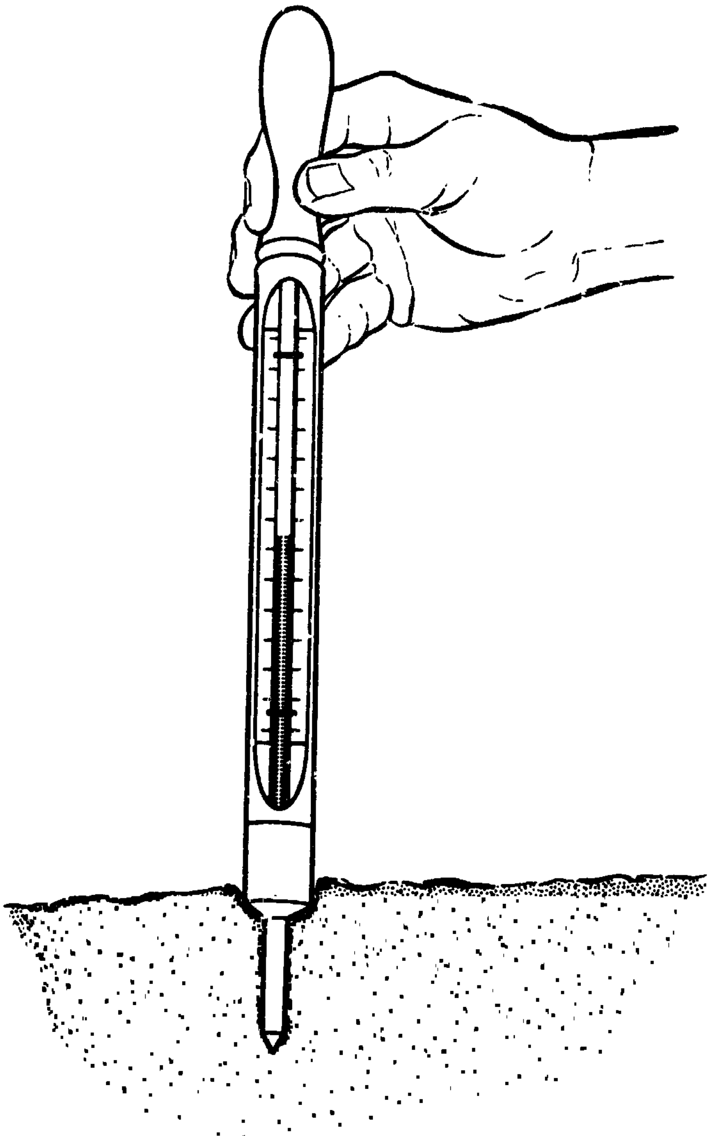

Fig. A-5. Brass-tipped soil thermometer constructed for *in situ* soil temperature measurements

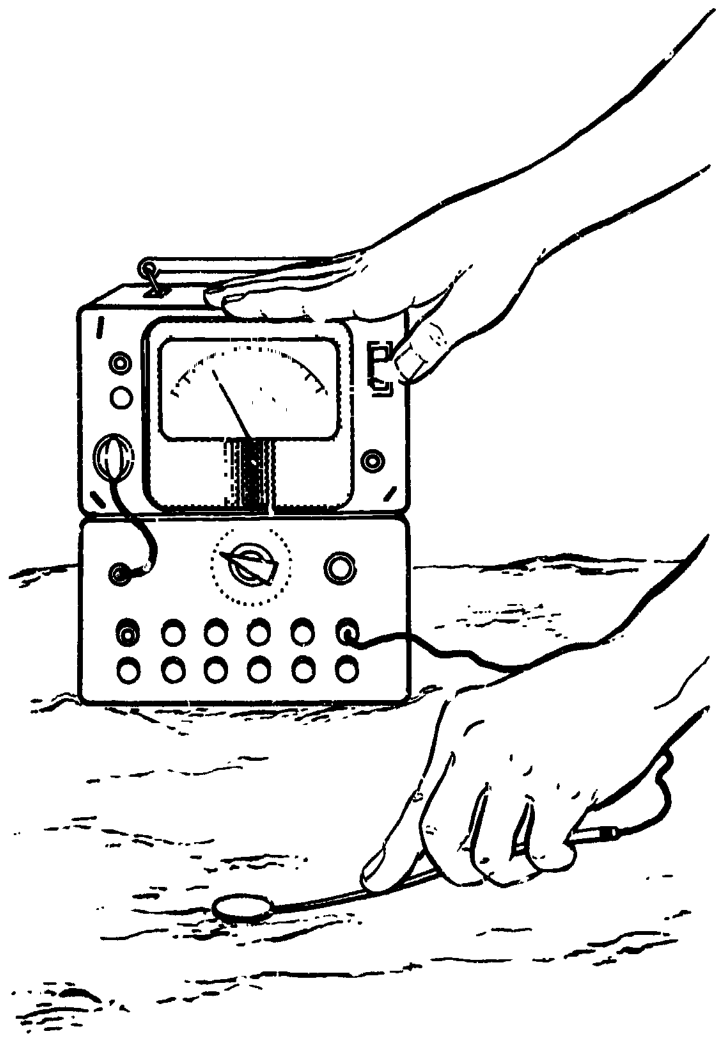

Fig. A-6. Portable, compact, lightweight instrument for measurement of soil and atmospheric temperatures; this instrument can be connected to a recorder and programmer for automatic sequential measurement and recording of temperature

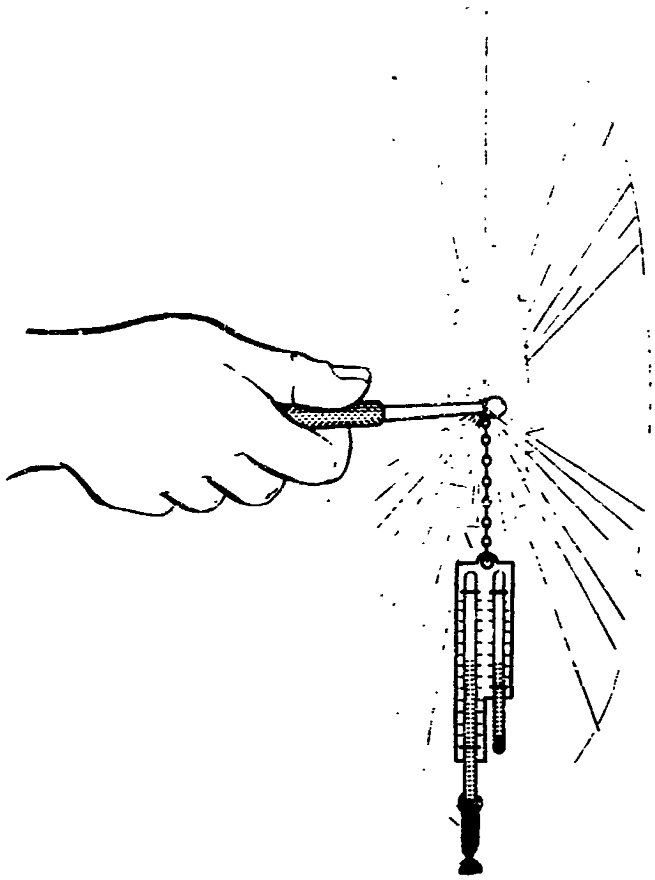

Fig. A-7. Sling psychrometer (in motion) for obtaining wet-bulb and dry-bulb air temperatures, in order to calculate relative humidity and dew point

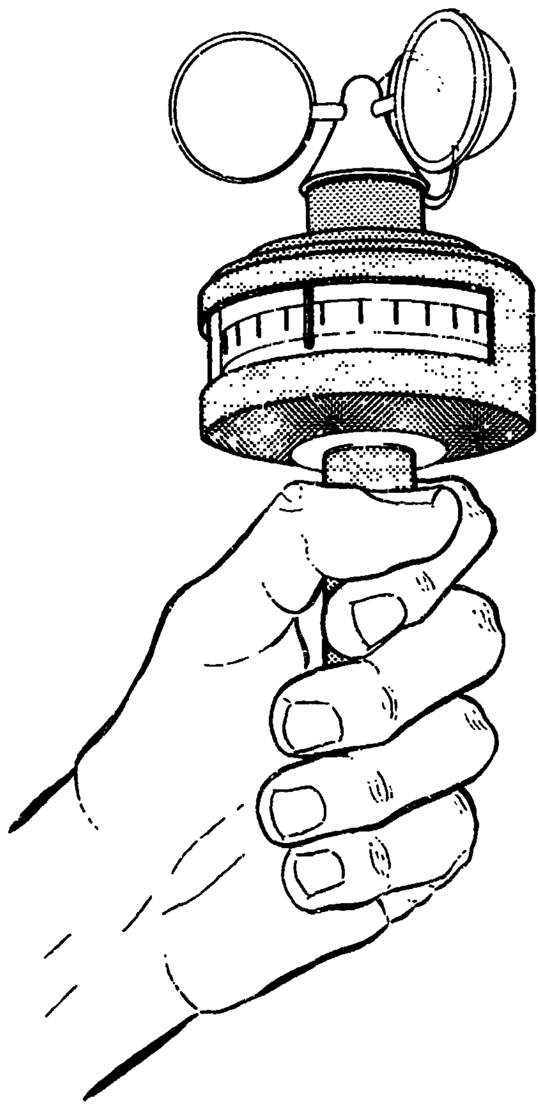

Fig. A-8. Portable hand anemometer for measurement of wind velocity at sampling site

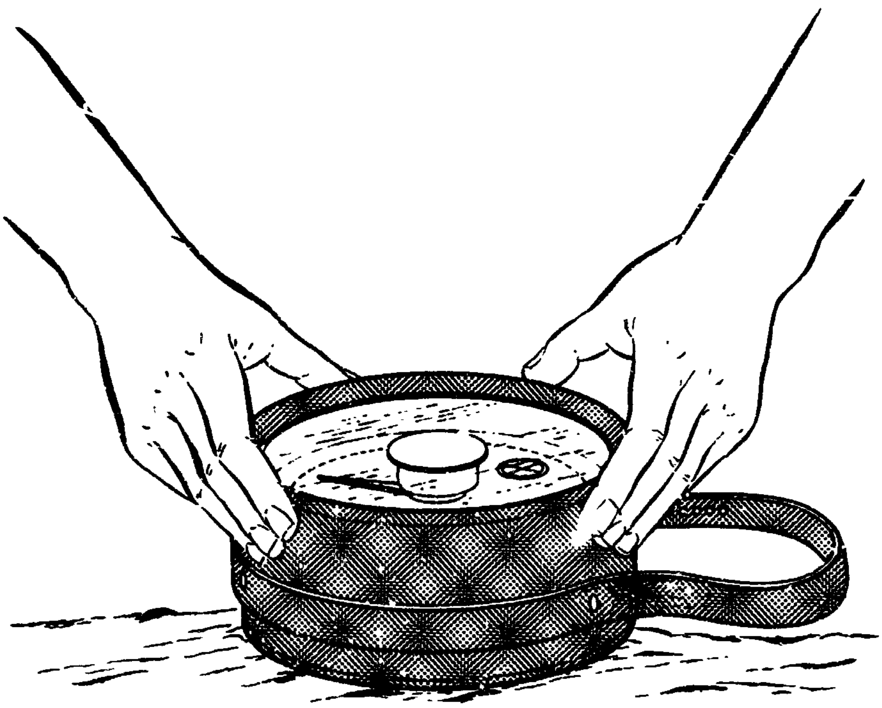

Fig. A-9. Rugged precision altimeter for measurement of elevation of sampling site

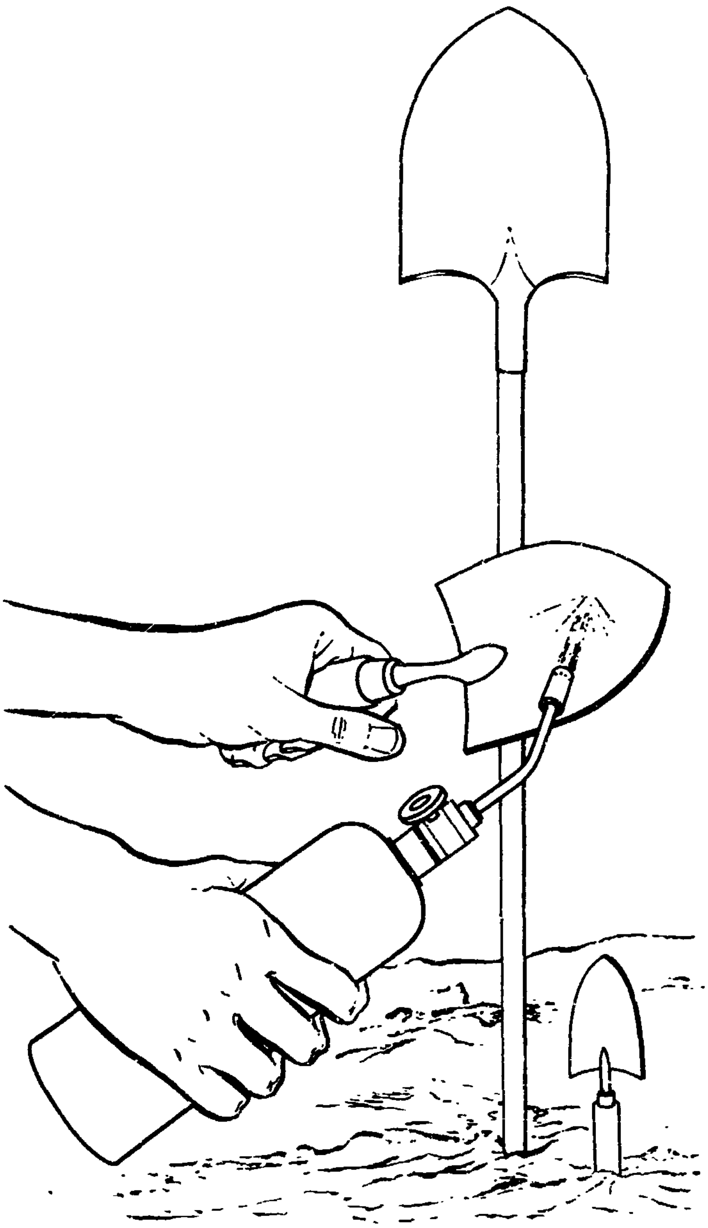

Fig. A-10. Sterilization of sampling shovel with propane torch; shovel (bottom right) is being cooled following sterilization procedure and prior to sample collection

Fig. A-11. *Top:* sterile sample sack being filled with dislodged soil from sampling site (care is taken not to contaminate the sample during the process of filling the sack); *bottom left:* properly filled, labeled, and tied sample sack with attached address label (and S-37 soil import authorization form, if necessary); *bottom right:* properly taped and sealed soil moisture tin containing the same kind of soil as in the sack

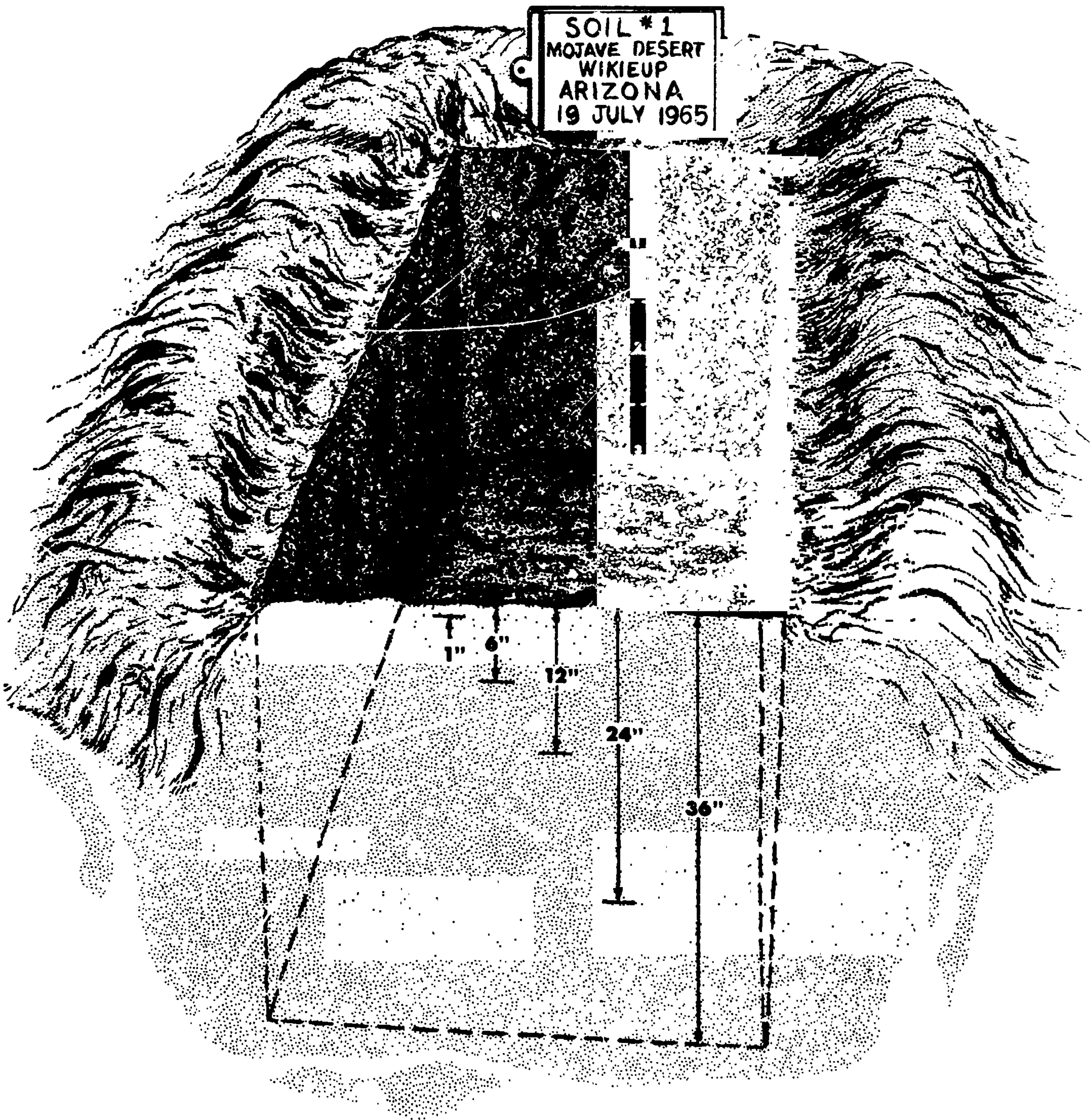

Fig. A-12. Excavated desert soil "profile" pit showing depth procurement levels for soil samples

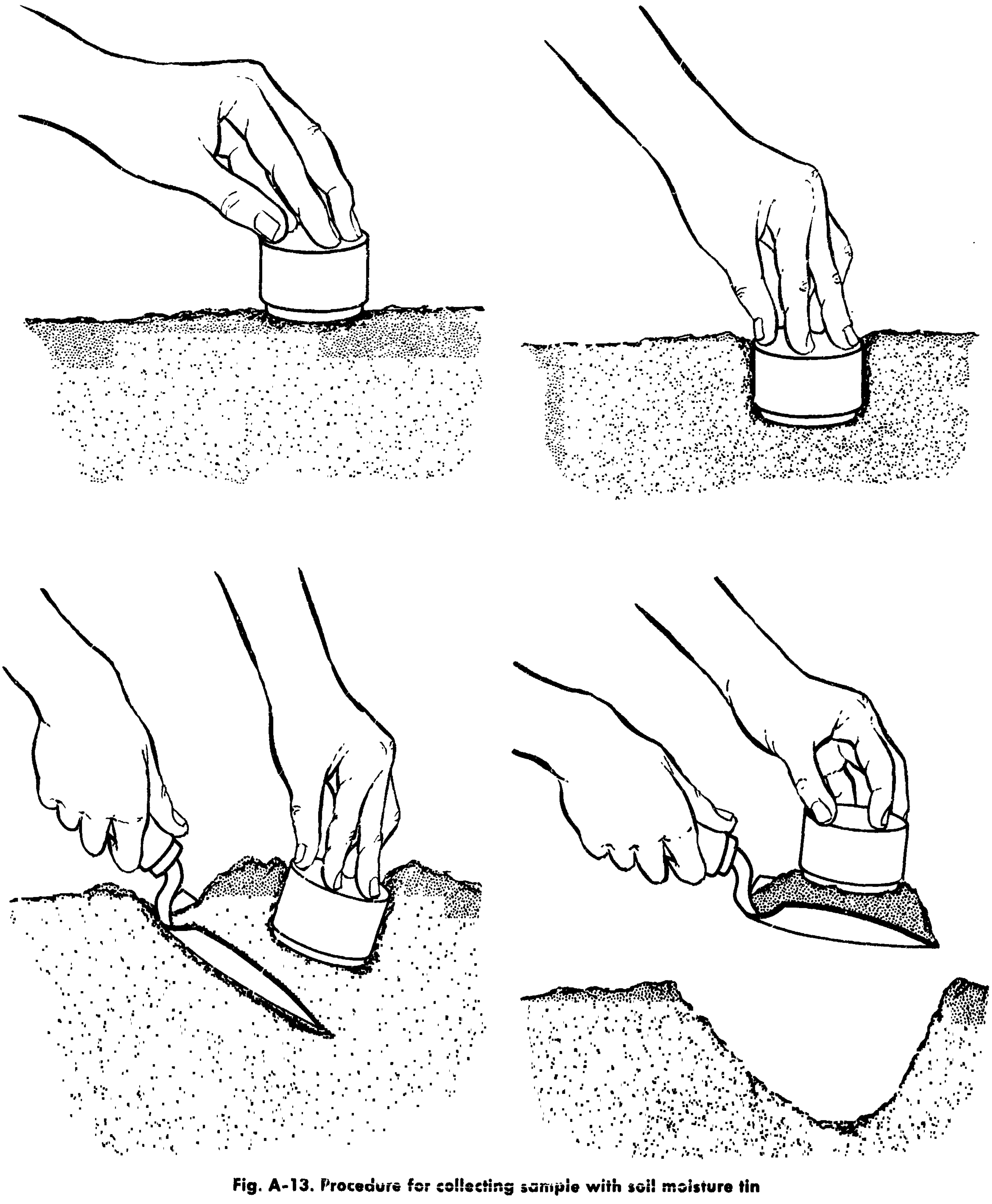

Fig. A-13. Procedure for collecting sample with soil moisture tin

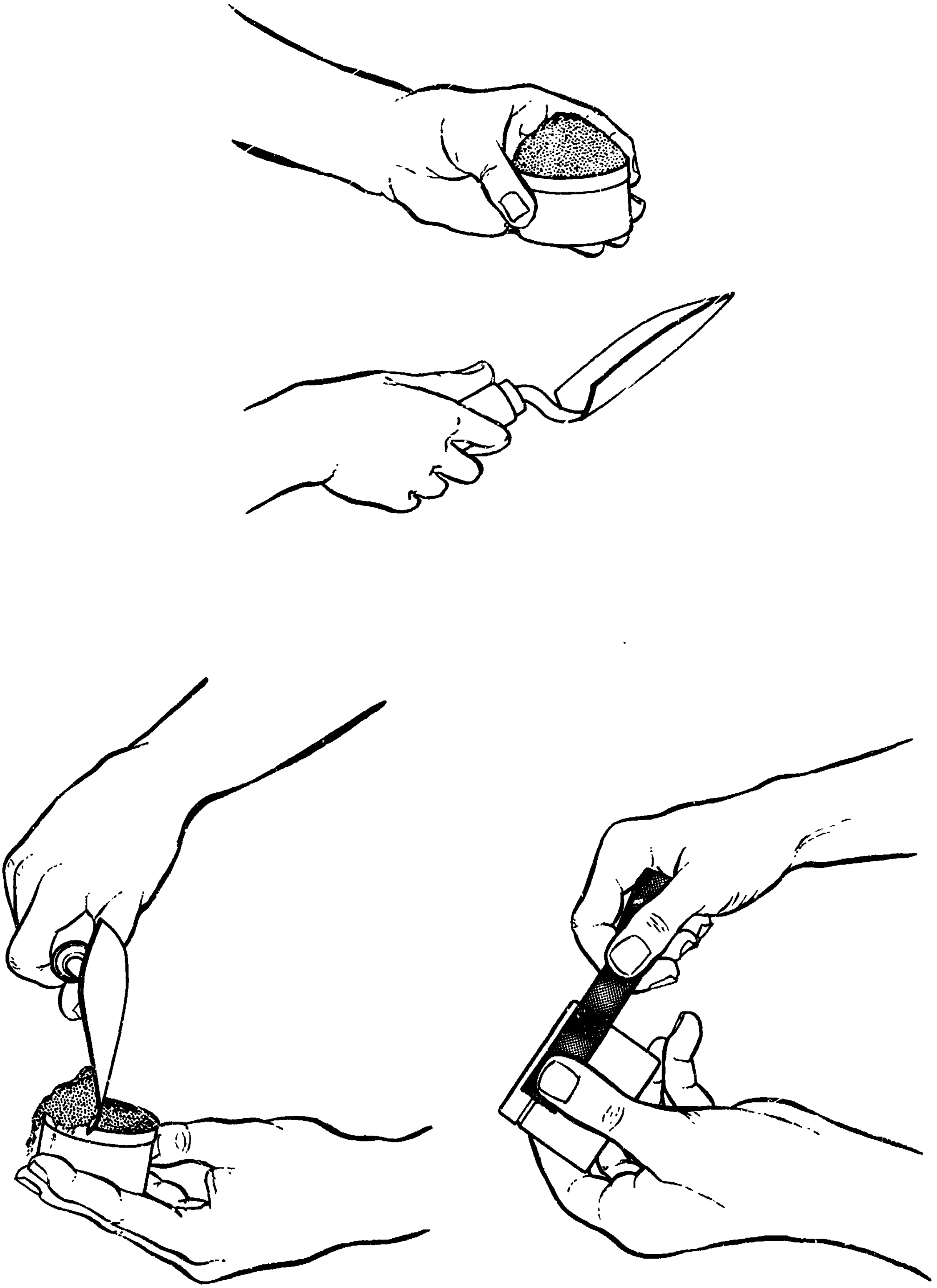

Fig. A-13. Procedure for collecting sample with soil moisture tin

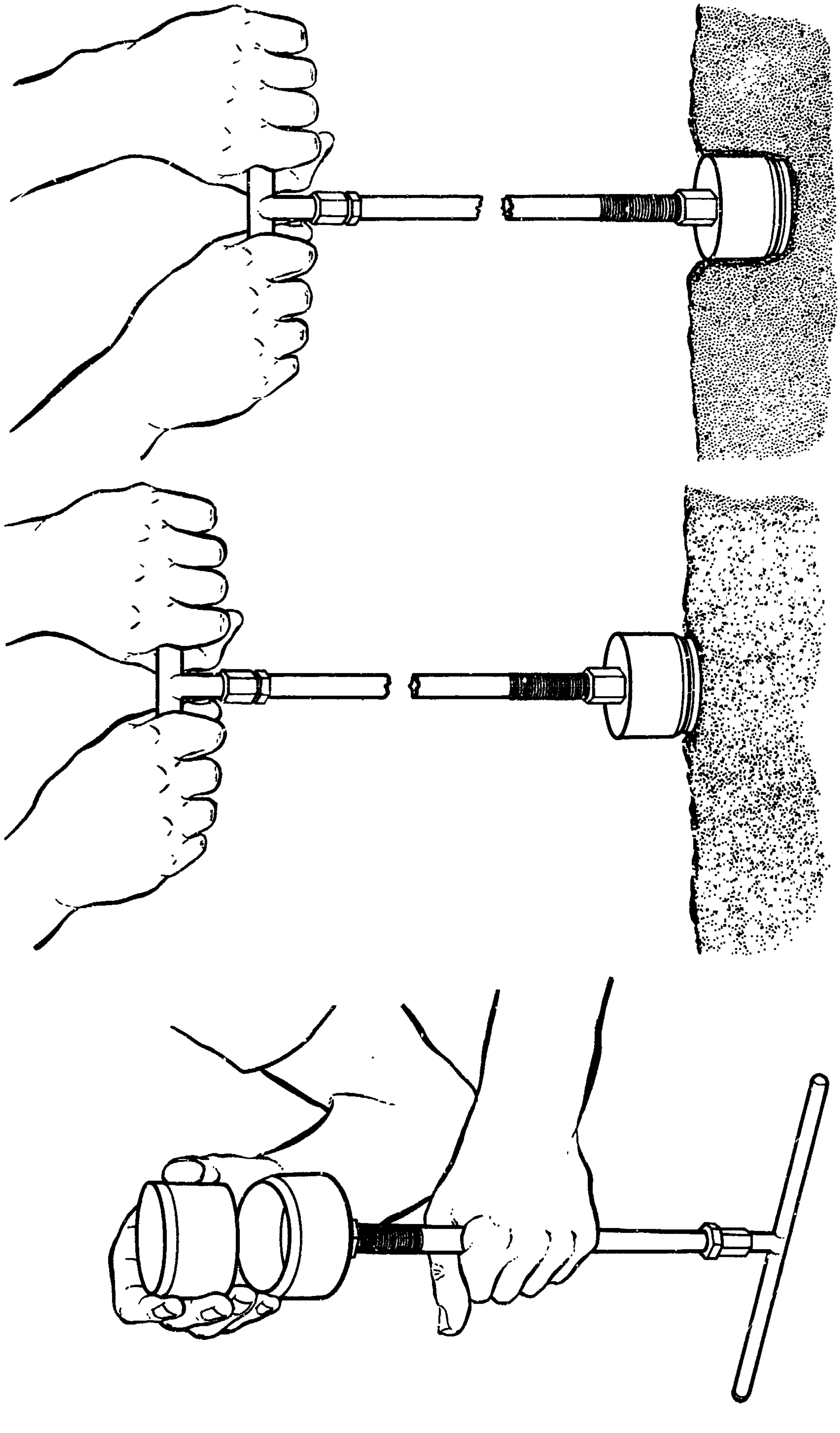

Fig. A-14. Procedure for collecting soil samples with soil moisture tin and sampler

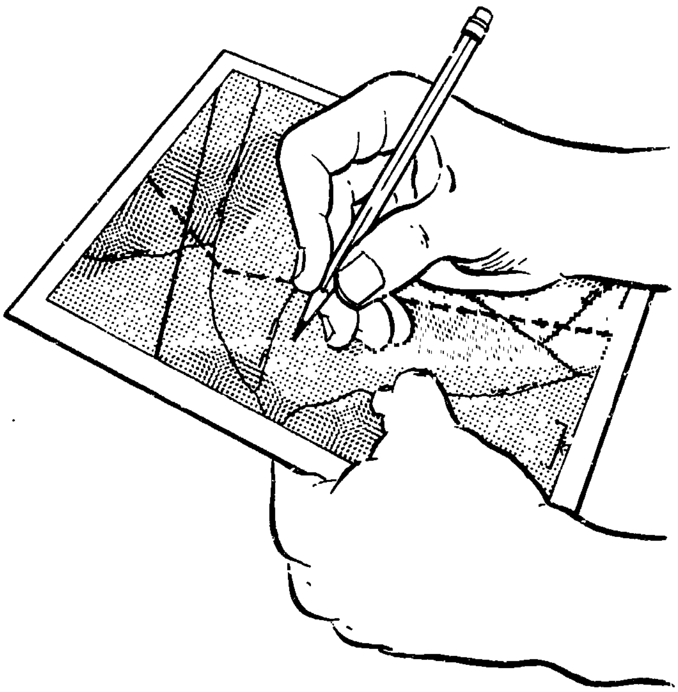

Fig. A-15. Locating soil sampling site on map for future reference

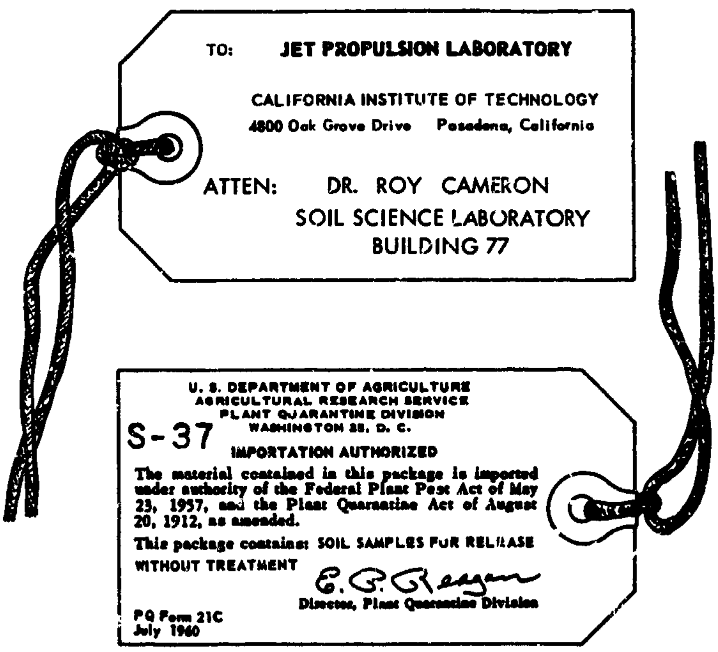

Fig. A-16. *Top:* address label for shipment of soil samples to JPL Soil Science Laboratory; *bottom:* U.S.D.A. S-37 form for soil importation authorization

APPENDIX B

Soil Sample Information Sheet and Accompanying Photographs

Photographs of site, area, soil surface, and exposed Soil Nos. 14–16 at White Mt. Summit (elev. 14,245 ft), White Mt. Research Station, White Mt. Range, Inyo National Forest, California, are given in Figs. B-1–B-4. Figure B-5 shows a Soil Sample Information Sheet for this location.

Fig. B-1. Frozen loessial soil beneath and between rough stones at summit soil site

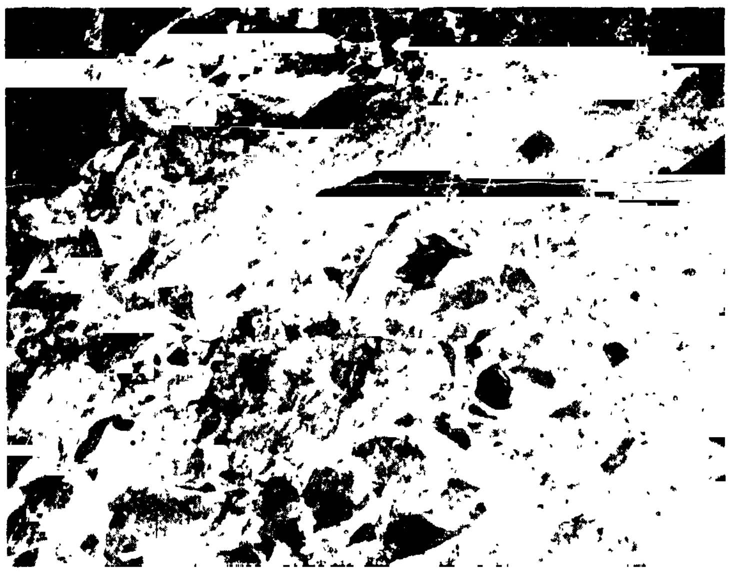

Fig. B-2. Algal-lichen growth on soil, and colorful crustose lichens on rocks; soil crusts subject to diurnal freeze–thaw cycles

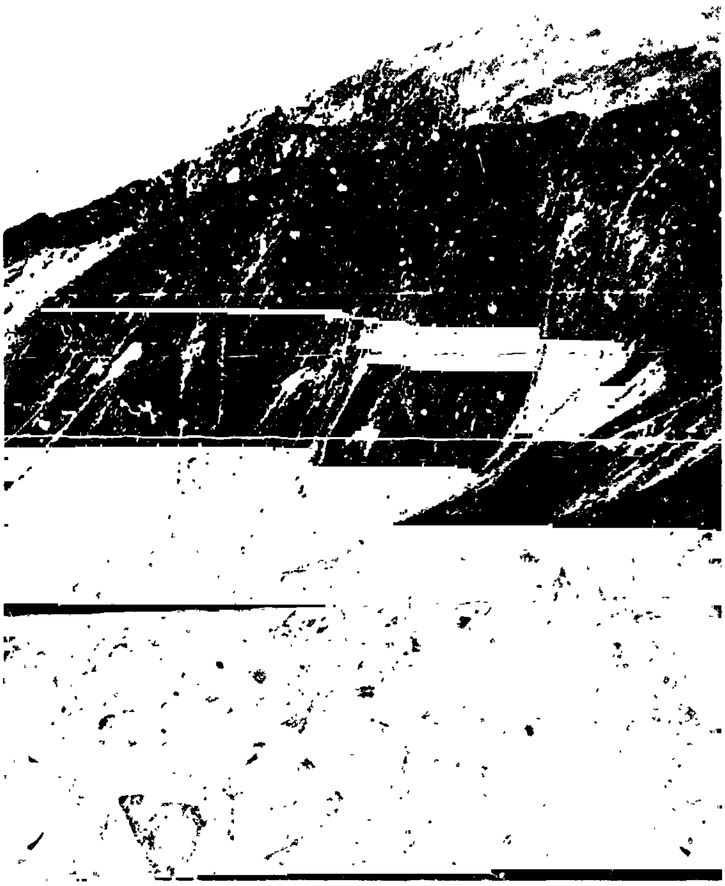

Fig. B-3. View toward Nevada and surrounding mountain peaks as seen from soil site at White Mt. Summit

Fig. B-4. Collecting surface soil crusts from patch of soil between rocks; rocky windbreak at right

SOIL SAMPLE INFORMATION SHEET

DATE: August 7, 1962

Location (Country, state or province, desert region, etc.):
California. Approximately 4.5 miles northwest of Barcroft Laboratory; White Mountain Summit, White Mt. Research Station, White Mt. Range, Inyo National Forest.

Topography of area:
Rough, precipitous, barren rocky mountains (Photo 3).

Position and slope of site:
100 ft. northwest of Summit Laboratory (Photo 4) at edge of west-facing precipice (Photo 3).

Erosion: Severe **Elevation:** 14,245 ft.
Parent Material: Quartz, plagioclase rocks **Drainage:** Excellent
Climate and weather: Polar; sub-glacial desert
Nearly always cold and windy. Snow-covered except for some weeks in the short summer. Hail, snow, and rain not uncommon, especially in the afternoon.

Natural Cover (vegetation):
None at soil site. Lichens on rocks and soil; algae on soil. Several low plants of Polemonium sp.; several short grasses.

Description of soil/geologic materials:
Microrelief of surface Sharp rocks with few small patches of bare soil
Structure: Azonal; frozen loess **Texture:** Stony sandy and clay loams
Color: Brown (air-dry or moist) **Other:** Algal-lichen soil crusts (Photo 2) Sub-surface soil frozen (Photo 1). Surface soil subject to diurnal freeze-thaw cycles.

Samples Taken: > 9 **Aseptic:** x **Not Aseptic:**

Soil #	Depth	# of Samples	Soil Moisture Tins
14	Surface 1/2"	4	2
15	1/2 to 6"	4	2
16	1'	1	1

Barometric pressure, 454 to 456 mm Hg.

Data: Environmental (micrometeorological): Nearly always windy, cold, stormy
Wind: 5 to > 75 m.p.h. (gauge failed) Cloud Cover: Low, fast-moving cumulous
Temperature: 25 to 47°F (air, 3') 19 to 93°F (soil surface) Humidity: 17 to 99% R.H.

Soil Tests: Physical: x Chemical: x
Microbiological: x (at Summit Lab.) Other: X-Ray; DTA; IR

In Situ: Temperature, moisture, relative humidity, oxygen, color, reflectivity, pH, Eh, unconfined compressive strength, density, infiltration rate.

Collector: R. Cameron/F. Morelli/G. Blank **Organization:** Jet Propulsion Laboratory

White Mt., California

Map References: Geological Survey: 1917 Soil Survey: None
Other:

Photographs (Area, site, exposed soil structure, etc.):
See Photos 1 thru 4. Additional pictures taken during subsequent collection of samples. Views taken of Fish Lake Valley, Owens Valley, Sierra Nevada Range, White Mt. Range.

Remarks:
Dangerous area. Hypoxia noticeable; altitude sickness common unless preconditioning undertaken at lower altitudes. Food, water, fuel, polar clothing necessary. Four-wheel drive vehicle and experienced mountain driver also necessary. Summit Lab sometimes available.

Fig. B-5. Soil sample information sheet

APPENDIX C

Suggested Minimum Equipment List for Soil Sample Collecting

1. Transportation vehicle adequately inspected and equipped prior to field departure (Fig. A-1). A four-wheel drive vehicle is preferable. Include spare tires, extra gasoline, oil, stout rope, some baling wire, an axe, vehicle tools, emergency flares, and all other usual vehicle equipment.
2. Cameras (preferably two). Take one camera for black and white film and a second for color negatives or color slides. Also include light meter, flash unit, and close-up lenses, if available. Film should not be high-speed, and should be adequately protected in tins or sacks.
3. Meter stick and/or other measuring device, clipboard, and paper for identification sign (Fig. A-12).
4. Sterilized, plastic-lined, canvas sample sacks (Fig. A-11), or other sterile sample containers.[6] Include a minimum of five sample sacks per soil sampling site of approximately 1 meter depth. Cement sacks or large burlap bags can be used to hold several smaller sample sacks.
5. Soil moisture tins (at least the same quantity as sample sacks) (Figs. A-13a–A-13g). Use soil moisture tin sampler if available (Figs. A-14a–A-14c). Include moistureproof tape (Fig. A-13g) and knife.
6. Address labels, twine, and S-37 soil importation authorization permits, if necessary (Fig. A-16).
7. Soil samplers and digging tools: sterilizable, small and large shovels (Figs. A-1 and A-10), geological hammer with pick head (Fig. A-1), large pick, mattock, crowbar, and other digging and sampling equipment.
8. Sterilizing equipment such as propane torch (Fig. A-10) or portable camp stove, and sufficient fuel supply.
9. Moistureproof, felt-tip marking pens, other pens, pencils, ruler, and notebooks.
10. Miscellaneous tools, e.g., pliers, wire-cutter, hammer, wrenches, tongs, etc.
11. Maps (Fig. A-15) (especially topographic), watch, stop watch, steel measuring tape, and pace counter.
12. Flashlights, "radarlights," and sufficient batteries, or lamps and fuel (Fig. A-1).
13. Various instruments for environmental and soil site measurements: thermometers (Figs. A-5 and A-6), sling psychrometer (Fig. A-7), small pH meter (Fig. A-4), hand anemometer (Fig. A-8), soil color charts, clinometer, Paulin Altimeter (Fig. A-9), aneroid barometer, etc. Also include sufficient distilled water supply in sturdy, rustproof containers (Fig. A-1).
14. Various personal items: include here such items as food, water, appropriate clothing (especially a hat), chapstick, sunburn lotion, sun glasses, shop towels, a first aid kit (include snake bite kit), a desert survival manual, gun and

[6]Soil moisture tins (approx. $1.20/doz.) and sample sacks, plastic-lined (approx. $1/sack), as well as many other items of soil equipment are available from Soiltest, Inc., 2205 Lee St., Evanston, Illinois.

ammunition, eating and washing utensils, soap and pans, knife and hatchet, knapsack, ground-cover, sleeping bag, camp stool and table, etc. It is highly suggested that at least two persons in good physical condition should be chosen for desert field trips. Keep people informed of your movements, and the time you expect to spend in remote areas. Be adequately prepared for desert field trips into rough, remote areas. Various difficulties for personnel and equipment are encountered and are not uncommon.

APPENDIX D

Nomenclature

adobe—a structural term applied to soils which form deep cracks and break into irregular, cuboidal or polygonal blocks upon drying.

algal-lichen soil crust—a soil crust formed on the surface of arid and semiarid soils which can be more or less easily separated from the surface of the soil and contains algae in various stages of parasitization or lichenization by fungi. See *soil crust*.

alkali soil—generally, a highly alkaline soil containing a high percentage of available sodium.

alluvial soils (entisols or secondary soils)—an azonal group of soils, developed from transported and relatively recently deposited material (alluvium) characterized by a weak modification (or none) of the orginal material by soil-forming processes.

alluvium—fine material, such as sand, mud, or other sediments deposited on land by streams.

arid climate—(a) a dry climate characteristic of hot, cold or temperate desert and semidesert regions in which precipitation effectiveness, water availability, or evaporation rate are such that a sparse vegetation of desert plants can exist or the land is barren, (b) a climate where the limits of precipitation vary widely according to temperature, with an upper limit for cool regions of $<$ 10 in., and for tropical regions of as much as 20 in.

aridisols—soils of dry places, commonly light-colored, mineral soils which are low in organic matter and either lack or have weak diagnostic horizons. These soils are common in arid and semiarid lands lacking a favorable moisture-temperature regime and dependent biota.

azonal soils—any group of soils lacking well-developed profile characteristics, either because of their youth (short geologic time period), arid climate, lack of biotic activity, or conditions of parent material, relief or drainage, that prevent the development of typical soil profile characteristics. See *aridisols* and *entisols*.

badland—nearly or partly barren, rough, broken land strongly dissected by streams or drainage channels. They are most common in arid and semiarid regions, where water has cut channels through soft geologic materials such as clays and soft shales, and including less weather resistant sandstones and limestones.

black alkali—a term applied to alkali soils containing a preponderance of very toxic sodium carbonate and sodium chloride salts. The black color is commonly due to dissolved and dispersed organic matter.

calcareous soil—a soil which contains a significant amount of carbonates (usually $CaCO_3$) and effervesces when tested with weak (0.1 N) HCl.

caliche—a more or less cemented deposit of calcium carbonate ($CaCO_3$) or of mixed calcium and magnesium carbonates ($MgCO_3$), characteristic of soils of desert and semiarid regions which lack sufficient leaching rainfall.

cementation—a process whereby soil becomes hard and dense through the accumulation of minerals such as silica, iron, manganese, salts, e.g., calcium and magnesium carbonates, and clay.

clay—(a) a soil separate consisting of particles of 0.002 mm or less in equivalent. (b) a soil textural class, (c) soil material that contains 40% or more clay, $<$ 45% sand, and $<$ 40% silt.

claypan—a hard, dense soil layer underlying the soil surface. It is especially hard when dry, and it is plastic or stiff when wet. Also called *hardpan*.

concretion—a nodular or irregular concentration of sedimentary rocks and tuffs. It is developed by the localized deposition of material from solution, generally around a central nucleus, and can be found as a weather-resistant body in some soils, e.g., lime concretion.

consolidated soil material—soil material made solid by cementation or other processes, from a previous fluid or loosely aggregated condition.

crustose- resembling a crust, or incrustation. A hardened external layer which is found in certain soil and rock lichens, especially in arid and semiarid regions.

decalcified soil—a soil which has had the calcium carbonate removed from the soil by leaching.

deep soil—generally, a soil that has a depth greater than 1 meter to rock or other strongly contrasting material.

degraded soil—a change of one kind of soil into a more highly leached one.

dehiscence—(a) the bursting of certain dry fruits at maturity, (b) the opening and discharge of pollen from the anther (sac-like organ on seed-producing plants), (c) the unfurling of leaves.

desalinized soil—a soil which has had salts, especially sodium compounds, removed by leaching.

desert crust—a hardpan, claypan, caliche layer or other binding material exposed at the soil–atmosphere interface in desert regions.

desert pavement—a pebbly, stoney, rocky, or similar surface layer of coarse material found in desert regions after the removal of fine material. Materials are frequently smoothed and polished by wind erosion, and browned or blackened when containing sufficient oxidized iron and manganese compounds, i.e., *desert varnish*.

desert soils—a group of soils which are azonal, intrazonal, or zonal, found in hot, cold, or temperate regions, frequently light-colored, well-oxidized, sometimes containing salt deposits, and developing under arid conditions and scant or absent macrovegetation.

desert varnish—a glossy sheen or coating on stones and gravel in desert regions. Also see *desert pavement*.

dispersed soil—(a) a soil which has had the compound particles or aggregates broken up into the individual component particles, such as by sodium in desert soils, (b) distributed or suspended fine particles, such as clay, in or throughout a dispersion medium, such as water.

dry sands—an azonal group of soils consisting of well-drained relatively cohesionless sandy deposits in which typical soil profile characteristics have not developed.

dune—a mound or ridge of loose material, usually sand, which has been piled up by the wind.

ecosystem—the biotic community, including all the component organisms together with the abiotic environment, forming an interacting system.

edaphic—(a) of or pertaining to the soil, (b) resulting from or influenced by factors inherent in the soil or other substrate, rather than by climatic factors.

entisols—see *alluvial soils*.

environment—all external conditions that may act upon an organism or soil and which influence its development.

erosion—(a) the wearing away of the land surface by running water, wind, ice, or other geologic agents, including gravity, (b) detachment and movement of soil or rock by water, wind, ice, or gravity.

escarpment—a steep face abruptly terminating high lands or frequently presented by the abrupt termination of stratified rocks.

evapotranspiration—the loss of water from a soil by evaporation and plant transpiration.

flaccid cacti—weak or limp cacti (various plants of the cactus family), which exhibit signs of water loss or desiccation of plant parts.

flocculated soil—a soil which has the individual grains or particles aggregated into small groups or granules.

flood plain—the nearly flat lands along streams or rivers that overflow during floods.

friable soil—soil that is easily crumbled in the fingers.

gently sloping land—land with an average slope varying between 3 and 8%.

gley soil—a soil developed under conditions of poor drainage and resulting in reduction of iron and other elements and in gray colors and mottles. Uncommon in desert soils, except as a relict or in nonarid micro-environments.

hardpan—a hard, dense soil layer underlying the soil surface. It is also synonymous with *claypan* or other cemented layers of soil such as *caliche*.

humus—the well-decomposed, more or less stable part of organic matter in the soil which has lost its original structure and has not yet been reduced to simple end-products.

impervious soil—a soil through which water, air, or roots penetrate slowly or not at all.

influx—a gain of matter or energy from outside assigned boundaries, such as an ecosystem, e.g., solar radiation, moisture precipitation, or sedimentation of dust.

inherited soil characteristic—any characteristic of soil that is due directly to the nature of the parent material as contrasted to those partly or wholly due to the processes of soil formation.

intrazonal soils—any group of soils with more or less well-developed soil characteristics that reflect the dominating influence of some local factor of relief, parent material, or age over the normal effect of the climate and vegetation.

Krotovina (crotovina)—a mineral accretion or deposit of organic matter formed by the filling of a channelway or former animal burrow. The burrow is usually found filled by material different from that of the soil surrounding it.

lacustrine deposit—material deposited in lake water and later exposed either by lowering of the water level or by elevation of the land.

landforms—multitudinous natural features that taken collectively make up the Earth's surface. These features are characterized according to size, shape, angles of slope and orientation, regardless of origin of development, e.g., hills, valleys, mountains, canyons, playas, alluvial fans, etc.

leached soil—soil from which the soluble salts have been removed by the percolation of water through the soil.

loam—soil material that contains 7 to 27% clay, 28 to 50% silt, and < 52% sand.

loess—material transported and deposited by wind and consisting of predominately silt-sized particles.

macrobiota—organisms visible by the naked eye and which do not need a microscope for detection purposes. See *macrovegetation*.

macrovegetation—plants which are visible to the naked eye and which do not need a microscope for detection purposes, e.g., shrubs, trees, grasses, and various flowering annuals and perennials.

mature soil—a soil with well-developed characteristics produced by the natural processes of soil formation and in equilibrium with the environment.

microclimate—(a) the climate (temperature–moisture–gas regime and related factors) surrounding a single soil particle, bacterium, or population of microorganisms on a soil particle, (b) the climate at the soil surface–atmosphere interface extending into the atmosphere to approximately 1 meter or more, (c) local climatic conditions, brought about by the modification of general climatic conditions by local differences in elevation and exposure.

microrelief—minor surface configurations or small-scale, local differences in topography, including mounds, swales, or pits that are only a few centimeters to decimeters in diameter and with elevation differences of several centimeters up to one or more meters.

mineral soil—a general term used in reference to any soil composed chiefly of mineral matter; especially characteristic of arid and semiarid soils.

nodule—a small, more or less rounded body generally somewhat harder than the enclosing soil, sediment, or rock matrix.

outflux—losses of matter or energy from within assigned boundaries, such as an ecosystem, e.g., heat radiation, water runoff, or solids carried off by erosion.

pans—horizons or layers of soil that are strongly compacted, indurated or very high in clay content. See *caliche*, *claypan*, and *hardpan*.

parent material—the unconsolidated mass from which the soil profile develops.

parent rock—the rock from which parent materials are formed. See *parent material*.

pedologist—a soil scientist, especially one who is concerned with the laws of origin, formation, and geographic distribution of the soil as a body in nature.

peneplain—a land surface reduced by erosion almost to base level so that most of it is approximately a plain.

permafrost—(a) permanently frozen material underlying the solum or upper and most weathered part of the soil profile, (b) a perennially frozen soil.

piedmont—lying or formed at the base of mountains. A piedmont alluvial plain is formed by the coalescence of alluvial fans.

plain—a large relief form or region of general uniform slope, comparatively level, of considerable extent, and not broken by marked elevations or depressions.

playa—(a) the shore, strand, beach or bank of river, generally sandy and sometimes salty, (b) the shallow central basin of a desert plain, in which water gathers after a rain and evaporates.

playa lake—broad, shallow sheets of water which quickly gather and almost as quickly evaporate, leaving dry or moist mud flats or playas to mark their sites.

pore space (voids)—the total space not occupied by soil particles in a bulk volume of soil.

relief—the elevations or inequalities of a land surface, considered collectively.

rhizosphere—that portion of the soil directly affected by plant roots.

rolling land—land which has compound slopes of 9 to 15%.

root zone—the part of the soil that is invaded by plant roots.

rough broken land—land with very steep topography and numerous intermittent drainage channels but commonly covered by vegetation.

rubble land—land areas with 90% or more of the surface covered with stones and boulders.

runoff—that portion of the precipitation on an area which is discharged from the area through stream channels.

salinization—the process of accumulation of salts in soil.

salty soil—a generic term applied to soils having characteristics which are caused by exposure to excessive amounts of soluble salts.

sand—(a) a soil particle between 0.05 and 2.00 mm in diameter, (b) a soil textural class, (c) soil material that contains 85% or more of sand; percentage of silt, plus 1.5 times the percentage of clay, shall not exceed 15.

sandy soil—a soil containing a large amount of sand.

scabland—land characterized by numerous outcrops of lava rock or scoria, and including land having numerous spots of barren, salty soil as is found in arid and semiarid regions.

second growth—new or continued growth by plants following an interruption of the growth period by fire, flood, hail, drought, landslide, or animal damage.

secondary soils—see *alluvial soils*.

silt—(a) a soil separate consisting of particles between 0.05 and 0.002 mm in equivalent diameter, (b) a soil textural class, (c) soil material that contains 80% or more silt and $<$ 12% clay.

single grain—each grain in a soil considered by itself, as in a structureless dune sand.

soil—a naturally derived body existing as a dynamic open system. It is a product of the environment, and on this planet it is composed of subsystems of a physical, chemical, and biotic nature. It has been developed under the combined influences of climate, time, mineralogy, topography, and biota, as well as other factors.

soil aggregate—a single mass or cluster of soil consisting of many soil particles held together, e.g., granule.

soil bulk density (**apparent density, volume weight**)—the mass or weight of oven-dry (105°C) soil per unit volume, including pore space.

soil characteristic—a feature of a soil that can be observed and/or measured and determined in the field or in the laboratory on soil samples, e.g., texture, structure, iron content, etc. Also see *soil property*.

soil climate (**solclime**)—the moisture and temperature conditions existing in the soil.

soil consistence—the relative mutual attraction of the particles in the whole soil mass or their resistance to separation or deformation, e.g., friable, soft, hard, cemented, etc.

soil creep—the downward mass movement of sloping soil which is usually slow and irregular.

soil crust—a brittle layer of hard soil formed on the surface of many soils when dry.

soil drainage—the rapidity and extent of removal of water from the soil by runoff and flow through the soil to underground spaces.

soil fertility—the quality of a soil that enables it to provide compounds in adequate amounts and in proper balance, for the growth of specific plants, when other growth factors such as light, moisture, temperature, and the physical condition of the soil are favorable.

soil genesis—the mode of origin of the soil, referring particularly to the processes responsible for the development of the solum from the unconsolidated parent material.

soil horizon—a layer of soil or soil material approximately parallel to the land surface and differing from adjacent related layers by degrees of physical, physicochemical, chemical and microbiotic properties.

soil kind—a collection of soils that are alike in specified combinations of characteristics.

soil map—a map showing the distribution of kinds of soil or other soil mapping units in relation to the prominent physical and cultural features of the Earth's surface.

soil microfauna—that part of the animal population within and on the soil which consists of individuals too small to be clearly distinguished without the use of a microscope. It includes primarily protozoa and nematodes.

soil microflora—that part of the plant population within and on the soil which consists of individuals too small to be clearly distinguished without the use of a microscope. It includes primarily bacteria, actinomycetes, fungi, and algae.

soil monolith—a mounted specimen of a soil profile or vertical exposure of soil taken from a cut in a bank or from a soil pit dug in the field.

soil morphology—the physical constitution of the soil including the texture, structure, porosity, consistence, and color of the various soil horizons, their thickness, and arrangement in the soil profile.

soil mottling—spots or blotches of different color or shades of color in the soil interspersed with the dominant color.

soil organic matter—materials in soil which are living, or are derived from plants or animals, and in various stages of decomposition.

soil population—the group of organisms that are indigenous or normally live in the soil.

soil porosity—the volume percentage of the total bulk of soil not occupied by solid particles.

soil productivity—an agricultural term for the present capability of a kind of soil for producing a specified plant or sequence of plants under a defined set of management practices.

soil profile—a vertical section of the soil through all its horizons and extending into the parent material.

soil property—a term commonly used synonymously with soil characteristics, except in a broader sense, i.e., soil physical, chemical, or microbiological properties.

soil science—that science dealing with soils as a natural body or resource and the properties of soils for various purposes.

soil separates—mineral particles, ≤ 2.0 mm in equivalent diameter, ranging between specified size limits. See *clay, silt,* and *sand.*

soil specificity—a soil which is limited to particular set of characteristics or conditions.

soil structure—the combination or arrangement of primary soil particles into secondary particles, units or peds. Secondary units may be, but usually are not, arranged in the soil profile in such a manner as to give a distinctive characteristic pattern.

soil subhorizon—a horizon or distinctive layer of soil occurring to some depth beneath the soil surface.

soil survey—the systematic examination, description, classification, and mapping of soils in an area.

soil textural banding—the occurrence of a soil band or separate denoted by its difference in texture from the adjacent soil layers or horizons.

soil texture—the relative proportions of the various groups of individual soil grains.

solum—the upper part of the soil profile, above the parent material, in which the processes of soil formation are taking place.

steep land—land having slopes ranging from 30 to 45%.

stone line—a layer within the soil profile consisting of stones, commonly deposited by stone-carrying flood waters.

stratified—composed of, or arranged in, strata or layers, as stratified alluvium. Those layers in soils that are produced by processes of soil formation are called horizons, while those inherited from the soil material are called strata.

structureless soil—a soil showing no observable aggregation or no definite and orderly arrangement of secondary soil particles or units along natural lines of weakness.

subsoil—(a) any part of the soil beneath the soil surface or below the immediate soil–atmosphere interface, (b) that part of the solum or upper part of the soil profile just above the parent material, in which the processes of soil formation are taking place, i.e., in agriculture, it is that part of the solum below plow depth (approximately 12 in.).

surface soil—(a) that part of the soil at the immediate soil–atmosphere interface to a depth of several centimeters, (b) agriculturally, it is that part of the arable soil commonly stirred by tillage implements to an equivalent depth of 5 to 8 in.

talus—fragments of rock and soil material collected at the foot of cliffs or steep slopes, chiefly as a result of gravitational forces.

terrace (geological)—a flat or undulating plain, commonly rather narrow and usually with a steep front, commonly bordering existing or previous rivers, lakes, or seas.

till (glacial)—a deposit of unstratified earth, sand, gravel, and boulders transported by glaciers.

transpiration—loss of water vapor from the leaves and stems of living plants to the atmosphere.

transported soil materials—parent materials of soils that have been moved from the place of their origin and redeposited during the weathering process itself or during some phase of that process, and which consist of, or are weathered from, unconsolidated formations.

tuff (tufa)—a rock composed of finer kinds of volcanic detritus, usually more or less stratified and in various states of consolidation. In calcareous deposits (travertine), it may be referred to as "calcareous tufa."

unconsolidated soil material—soil material in a form or state of loose aggregation.

very steep land—land or slopes of more than 45%.

voids—see *pore space.*

weathering—the physical and chemical disintegration and decomposition of rocks and minerals.

xeric (xerophytic)—arid, or deficient in moisture. Vegetation characteristic of desert regions; thorny brush, cacti, shrubs, small flowering annual and perennial plants, crustose lichens, etc.

xerophytic (xerophilous)—*see xeric.*

young (immature) soil—(a) an imperfectly developed soil in terms of soil characteristics and horizons, (b) a soil having a profile with slightly compact subsoil horizons.

zonal soils—any group of soils having well-developed soil characteristics that reflect the influence of the active factors of soil genesis, especially climate and living organisms (primarily vegetation).