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# Colorado Plateau Vegetation Assessment and Classification Manual


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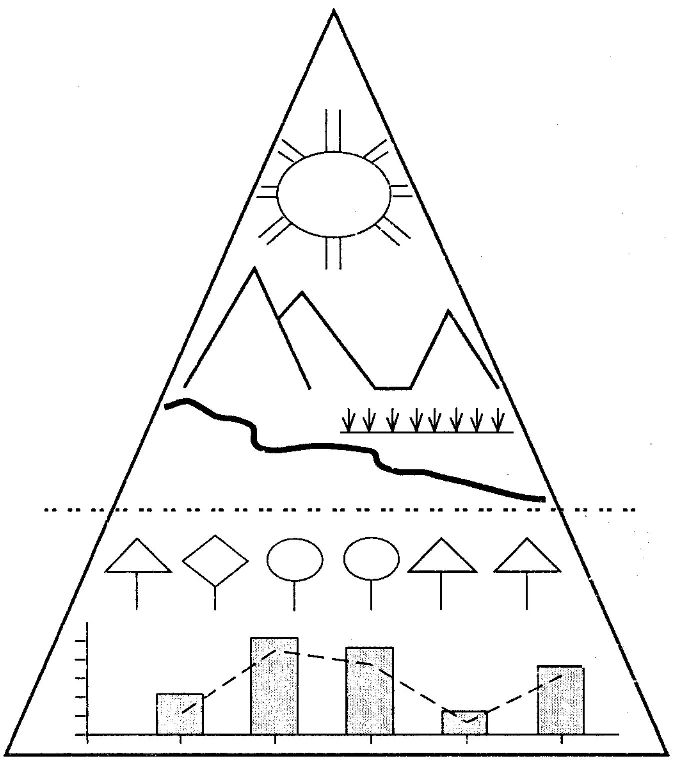
**Technical Report NPS/NAUCPRS/NRTR-94/06**


**National Park Service**
**U.S. Department of the Interior**

**Colorado Plateau Research Station**
**at Northern Arizona University**

Northern Arizona University

## National Biological Survey
## Colorado Plateau Research Station
## Northern Arizona University

The National Park Service (NPS) Cooperative Park Studies Unit (CPSU) at Northern Arizona University (NAU) was originally established in October 1988. The unit is unique in that it was conceptualized for operation on an ecosystem basis, rather than being restrained by state or NPS boundaries. The CPSU was established to provide research for the 33 NPS units located within the Colorado Plateau, an ecosystem that shares similar resources and their associated management problems. On November 11, 1993, the unit was transferred into the National Biological Survey and renamed the Colorado Plateau Research Station (CPRS).

Utilizing the university's physical resources and faculty expertise, the CPRS facilitates multidisciplinary research in Department of Interior areas on the Colorado Plateau, which encompasses four states. The CPRS provides scientific and technical guidance for effective management of natural and cultural resources within those areas.

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July 1994

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# INTRODUCTION

## Overview: Motivations and Planning for Vegetation Surveying and Mapping

In most cases the area or region where the vegetation is to be surveyed, classified, and mapped will be defined *a priori* on the basis of some sort of management need within defined geographic boundaries. Needs may vary from watershed, viewshed, or fire management to basic inventory and monitoring and wildlife habitat evaluations. The extent of geographic boundaries may range from small areas, such as research natural areas to entire park units, and from artificial entities (e.g., park units) to ecosystems (e.g., the Colorado River riparian system). In some instances, single purpose, site-specific vegetation classifications may be made. An example of the latter could be a description of the habitat of a restricted population of a T&E species. Generally, larger areas at the landscape scale are involved.

## The Classification System

The Colorado Plateau Vegetation Advisory Committee (CPVAC) has agreed that the vegetation classification system used by the National Park Service (NPS) areas on the Colorado Plateau will conform to a classification system developed by Drs. John Spence, William Romme, Lisa Floyd-Hanna, and Peter Rowlands (SRFR). The SRFR classification scheme has its roots in the system developed by Brown, Lowe, and Pase (1979:7, 11) (BLP). Originally, the BLP system was highly considered as a standard classification scheme for the Colorado Plateau. However, as we tried to adapt it, it became clear that it could not meet the needs of the Colorado Plateau park units without substantive modification. The result, SRFR, was sufficiently distinct in both philosophy and content (e.g., the institution of a Biotic Province category, elimination of the Climate category, and integration of elevational/latitudinal climatic gradients into a Zone category) that it is essentially a new system. The reader is referred to Appendix I for a full description and guide to application of the SRFR classification system for the Colorado Plateau as well as its relationships with other systems such as UNESCO and, in particular, BLP. Users are encouraged to read the original BLP reference as well as "Biotic Communities of the Southwest" (Brown 1982) in order to gain a more complete understanding of this system, its uses, advantages, disadvantages, and its relation to SRFR. Figure 1 illustrates the conceptual relationships of the BLP classification categories while Table 1 compares the results of applying the two systems to the same vegetation associations.

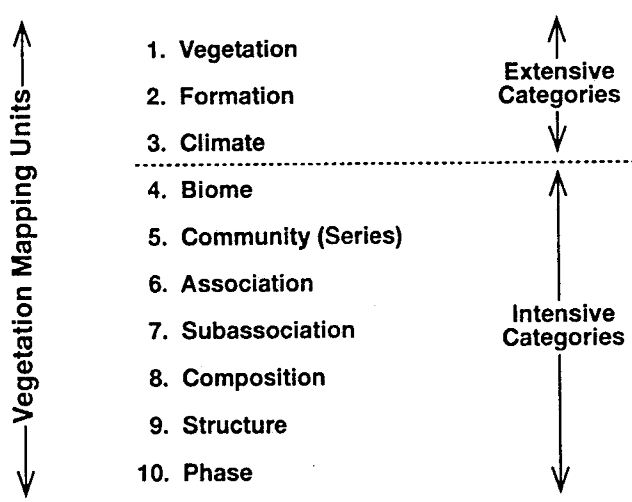



*Figure 1. Conceptual model of the Brown, Lowe and Pase Vegetation Classification.*

Table 1. Comparison of the BLP and SRFR classification schemes with respect to Ponderosa pine (*Pinus ponderosa*) associations.

| | |
|---|---|
| BROWN, LOWE AND PASE | |
| 1,100 Nearctic Upland Vegetation | VEGETATION |
| 1,120 Forest and Woodland Formation | FORMATION |
| 122 Cold Temperate Forests and Woodlands | CLIMATE |
| 122.3 Rocky Mountain Montane Conifer Forest | BIOME |
| 122.32 Pine Series | SERIES (COMMUNITY) |
| 122.321 *Pinus ponderosa* association | ASSOCIATION |
| 122.3211 *Pinus ponderosa / Arctostaphylos patula* subassociation | SUBASSOCIATIONS |
| 122.3212 *Pinus ponderosa / Quercus gambelii* subassociation | |
| SPENCE, ROMME, FLOYD-HANNA AND ROWLANDS | |
| 01 Colorado Plateau Province | PROVINCE |
| 13 Montane Zone | ZONE |
| 1301 Forest and Woodland Formation | FORMATION |
| 13011.03 *Pinus ponderosa* Series | SERIES |
| 1301.031 *Pinus ponderosa / Arctostaphylos patula* association | ASSOCIATIONS |
| 1301.032 *Pinus ponderosa / Quercus gambelii* association | |

## Planning Considerations

It is important to point out that a well-written and peer-reviewed proposal should precede all but the most trivial vegetation surveying projects so that the project leader has a good grasp of the scope, objectives, and goals of the project and can communicate these both to park mangement and to co-workers. Such a proposal should follow guidelines put forth by the individual regional offices and should also contain, in addition to a precise and well-written statement of the scope of work, a spectrum of approaches and alternatives as well as an analysis of costs in dollars per surveyed hectare.

Planning considerations also need to be given to the methods used in the vegetation classification procedure. In the case of a large data set (e.g., one obtained from satellite-based remote sensing and using a Geographic Information System [GIS]), a classification may be supervised, i.e., a classification developed by the researcher or resource manager, through extensive field work and ground truthing, and imposed on the remotely sensed data. Or, it may be unsupervised, i.e., computer-generated using ratios of differentially reflected spectral bands with a minimum of intervention from the researcher or resource manager. Realistically, however, even an unsupervised classification will require extensive ground truthing and modification in order to be valid. Generally, these sorts of extensive, remotely-sensed databases will not be available to most park units. However, in a few cases they will, either directly (very rare) or through a third-party contract or work-order. Whether the latter approach is taken may depend upon a favorable cost-benefit ratio and favorable response to a proposal (RFP). Highly accurate vegetation surveys and classifications may also be constructed when sophisticated, high elevation remote sensing and a GIS workstation are not available. The lack of sophisticated equipment should not be seen as a constraint. With the proper care, a project relying upon low elevation (<10,000 ft) aerial photographs, intensive field work, manual surveying and mapping, readily available desktop computer analysis packages such as the Cornell Ecology Package (Mohler 1987) or simple association tables (Muller-Dombois and Ellenberg 1974) can yield equally credible and useful products. The simplest, but by no means invalid, approach is the judicious classification of the data set based upon the project leader's experience with the local and regional vegetation and flora and manual mapping. A very large project could include all of these approaches.

## Scope of this Document

It is beyond the scope of this document to review all the above concerns in any detail. We only hope we can provide assistance at the field level in surveying concrete stands of vegetation. Keep in mind that the methods of vegetation measurement which are eventually chosen, as well as those used to manipulate the data, will necessarily affect the eventual interpretation of the data and therefore the classification. This is especially true below the series level.

The methods for vegetation classification and mapping presented in this manual are semi-quantitative and intended for fast, economical collection of vegetational data over large areas. A general assumption is that the vegetation classification will be at or above the series level. The methods provided can be used below the series level but should be considered as a minimum level of effort. A very thorough description of many of these methods as well as concrete examples of classification results can be found in Warren et al. (1982). Provided that funds and staff are available, no park unit should be dissuaded from employing the more intensive semi-quantitative or fully quantitative methods which are described in such basic texts as Shimwell (1971), Mueller-Dombois and Ellenberg (1974), and Bonham (1989).

In the field, the investigator must know or learn the major persistent perennial plant species of the area, in particular the woody plants. This manual will not address issues relating to plant identification. A knowledge of local floras including the common annual grasses and ephemerals will be very helpful if not essential. Familiarization with common species contained in local herbaria is recommended.

## Equipment Required

The field investigator will need:
(1) a notebook with field sheets and pages for recording community data, photography, and plant collection data;
(2) several ballpoint pens, a technical fountain pen with indelible india ink or a 2.5 hardness pencil (felt tip pens are not recommended since the ink smears or runs when wetted);
(3) plant collection materials (a press, plastic sample bags, garden shears, and digging tool are most usual; see Appendix II);
(4) a camera (documentation backs are desirable but not necessary);
(5) plant checklists and floras;
(6) if available, maps, aerial photographs, and/or GPS equipment necessary for navigation and location in the landscape;
(7) a 30 m or longer tape measure with 1 or 2 chaining pins;
(8) a Brunton or Silva compass; and
(9) an Abney level, clinometer or similar instrument for slope angle determination.

# PRELIMINARY ANALYSIS

Prior to the beginning of field work, some sort of preliminary analysis or reconnaissance should be made. This could take the form of an examination of existing remotely sensed data (aerial, satellite photographs, etc.) or even examination of the vegetation and topography of an area from a high vantage point. In any case, the result would be a preliminary field map. This can take the form of a topographic map or aerial photograph (or both) upon which are delineated vegetation "polygons" or "mapping units." These polygons are irregular areas drawn on a map or aerial photo and which conform to putative stands of relatively homogeneous vegetation. The upper or lower limits to the size of a polygon will depend upon the purposes of the vegetation survey as well as the scale of mapping and classification. For example, mapping motivated by avian habitat evaluations will have lower limit constraints dictated by the size of the permanent, avian monitoring plots (usually about 50 m in radius) and would probably be done at the association or sub-association level. Mapping of vegetation at the scale of a landscape will generate large polygons (tens to hundreds of hectares or greater) at the series level of classification. Once a preliminary map is available, all of the individual polygons, or a stratified random sample if large numbers of polygons are involved, should be systematically visited in order to (1) determine their validity as homogeneous stands of vegetation, i.e., ground truthing and

(2) survey and classify the stand of vegetation. Some polygons, in part or in whole, may turn out to be artifacts created by shadows, topographic features, or soils. These should be eliminated or recombined (melded) into adjacent polygons of the same relatively homogeneous vegetation type. Obviously high elevation, low resolution photographs are going to produce more of these artifacts than large scale photos. Ground truthing is especially important in verifying polygons produced by analysis of remotely sensed data where there is a lack of prior intimate knowledge of the region to be mapped.

## SAMPLE SITE SELECTION

Walk or drive through the geographical area you are going to map, familiarizing yourself with the terrain. Along with the preliminary analyses described above, this will aid in determining sample site number and location.

### Numbers of Samples

The concrete stand or stands which you choose to survey within an affected polygon should be representative of that polygon. A number of sample sites within each vegetation type, possibly involving several vegetation polygons, may be needed to ensure adequate characterization of the community. The number needed relates in part to terrain and community variability. Widely distributed vegetation types with high variability will require a large number of samples; those of limited geographical distribution and low variability will require fewer samples. A range of 3-50 sampling sites per vegetation type, with a goal of 10-20, is recommended. The sample sites should be evenly distributed among the vegetation polygons classified as that type. Warren et al. (1982) used between 1 and 94 samples (average 24) when classifying and mapping the vegetation of Grand Canyon National Park. Multiple sites within a large polygon could be located either systematically or randomly depending upon the purposes of the project. If hypotheses are being tested, as opposed or in addition to simple description, then random location is advised.

### Site Placement, Edge Effects, and Gradients

The ecological reality is that plant communities change individualistically along both temporal and spatial gradients. Absolute boundaries can seldom be defined (Whittaker 1975). Knowing these constraints, the survey site itself should be as homogeneous as possible, with relatively uniform soils, aspect, slope, and vegetation. Confine your attention to this area. Avoid the tendency to inadvertantly extend the sample site beyond this relatively uniform area. Guard against allowing the presence of prominent plants outside the sample site to influence your judgement about plants inside. For example, an exceptionally large tree outside the sample site may cause you to overestimate the importance of the ones on site. A single sample site in a small polygon should be as close to the geometric center of the polygon as possible in order to avoid edge effects. Multiple sampling sites within a large polygon should also be located in such a fashion as to minimize the sampling of edges, or where ground slope and/or aspect vary, or in certain cases along soil type boundaries. Sharp environmental gradients will likely be encountered and data collected will show high variability in vegetation composition along the gradient (Beta-Diversity), producing a problematic classification. Decisions on placement and number of sampling sites should be made *a priori* by the project leader/investigator with adaptive changes made in the field as necessary.

### Size of the Sample Site

The size of the sample sites will vary according to circumstance. Where vegetation is more or less uniformly distributed (i.e., not patchy) and visibility is good, sample sites should have an imaginary boundary that includes about 1 hectare (2.5 ac). Where visibility is poor, i.e., where vegetation is so thick that you cannot see very far, more numerous smaller sample sites are desirable and the sample site reduced to about 0.5 hectare or less. Where the vegetation stand is limited in extent, e.g., around springs or hanging gardens, the sample sites may be only a few meters wide. Where vegetation is patchy, a choice of larger sample sites is advisable. Where vegetation is uniform, sample sites may be smaller.

# USING THE VEGETATON DATA SHEETS

## Initial Entries

Complete the CPVAC Vegetation Record. Enter your name, today's date, land ownership, name of the land administrative unit (if appropriate), state and county abbreviations, a name for the relevé (if you wish), and a description of the location of the relevé. Finally, estimate the aerial extent of the relevé (sampling plot). A square 100 m (328 ft) on a side is a hectare or 2.47 acres. Record the area and circle Ha.

## Physical Features and Georeferencing

### Topographic Data

Determine ALL the landscape-terrain features in that geographical area. Note slopes, aspects, drainages, soil type changes, etc.

***Percent Slope***

Record Slope Percent. Slope percent is the change in elevation (rise) divided by distance (run) times 100. Estimation is usually good enough but can be checked with Brunton compass or clinometer. Record slope percent on the face of the CPVAC Vegetation Record form in the box provided.

***Aspect***

Record Aspect. Aspect is the direction the slope faces. Circle the best choice on the face of the CPVAC Vegetation Record form. A compass may be useful if you are disoriented, but do not record the compass azimuth.

***Elevation***

Record the elevation of the relevé in m (indicate on form, as needed). A topographic map will yield good enough elevation information for our purposes.

***Areal Extent***

Record the areal extent of polygon (in ha or $m^2$), if known.

### Georeferencing Data and Information

These data may be available at the time of survey or added later when available/convenient. They will be necessary to establish a GIS database if and when this becomes a consideration.

***UTMs, Lat./Long.***

Record Universal Transverse Mercator Grid Location. All data collection sites must be referenced to the Universal Transverse Mercator Grid (UTM). Universal Transverse Mercator Grid ticks appear in blue on the borders of all USGS topographic maps at 1000 m intervals. They are reported in the form represented by this example: 3588010mE, 3588010mN.

***Zone for UTMs***

The UTM coordinate system is based on a series of 60 zones worldwide, each covering 6 degrees of longitude in a north-south strip.

***Airphotos***

Record this information if it is available. Airphotos are generally numbered according to a flight path/pattern. In addition to a number, the date, elevation, and flight direction are also recorded on the aerial photograph or transparency.

***Ground Photos***

Take several good photographs of each site with a documentation back (if possible). Color slide film with low ASA (Kodachrome 25 or 64; Ektachrome 100; Fujichrome 50 or 100) should be used. Prints can be made from the slides if needed. Vegetation is difficult to photograph and nearly impossible in flat lighting conditions. Take photos from a high vantage point and in sunlight when possible. Forest vegetation is best photographed along roadways since full tree height can be seen unobscured by foreground vegetation. When the slides and or photos are developed, they should be labelled with the date, location (park name, area, district, township and range, etc.), polygon no., plot no., and recorder and enclosed in a film archiving envelope which should be attached to the CPVAC Vegetation Record form.

### Soils and Erosion Information

Soil series and associations can be added later, if available. However, dissection rating should be added in the field as should soil texture and particle size class distribution. Soil characteristics are ecologically significant, and some information should be recorded about them. Pedon names can be obtained from third order (or better) soil surveys sometimes available from the Soil Conservation Service. Record this data if available and time permits.

***Soil Series***

A group of soils that have about the same profile, except for differences in texture of the surface layer or of the underlying material. All the soils of a series have horizons that are similar in composition, thickness, and arrangement (Taylor 1980:113).

***Soil Formation***

The biogeochemical processes involved with the formation, over time, of a soil layer or layers from parent material.

***Soil Color***

If available, this can be determined from standard Soil Conservation Service soil color charts.

***Dissection***

Describe the dissection rating (spacing) as great, medium, little, or minor (<10 m wide) erosion channels and, thus, degree and activity of erosion disturbance. Dissection = Pedestalling: The process of forming a small elevated plane by the erosion of adjacent areas from around an object. Does not pertain to pedestals created by heaving from frost action (Clark 1980:32).

***Soil Surface Composition***

Estimate the percentage of the ground covered by rocks according to Table 2, and record the answer.

***Soil Texture***

The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt, silt loam, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine" (Taylor 1980:144).

Estimate texture by rolling a pinch of soil between the fingers. Unfortunately, learning to qualitatively estimate soil texture is difficult to describe, and quantitative analysis is too exact and expensive for our needs. Agricultural extension stations are sometimes willing to show you how to classify soils by feel. Approximately, sand always feels gritty unlike silt and clay. Clay feels slick like talcum powder and becomes sticky when wet. Silt does not become sticky when wet. Estimate sand, silt, and clay content by feel and write the percentage in the appropriate box. Describe the results as one of these textures: sand, silt, clay, loam (approximately equal amounts of silt and sand with a little clay added), silt-loam, clay-loam, or sand-loam (perhaps the most common soil texture in the Southwest).

Table 2. Soil particle size definitions.

| Particle | Size Class |
|---|---|
| Boulders and rocks: | > 190 mm |
| Cobbles: | 64 mm < X < 190 mm |
| Gravel: | 2 mm < X < 64 mm |
| Sand : | 0.05 mm < X < 2 mm |
| Silt: | 0.002 mm < X < 0.05 mm |
| Clay: | < 0.002 mm |

## Landform Information

Record Landform data. Landform data are of secondary importance. They are useful for describing arrangement of vegetation types in the landscape. Landform definitions appropriate to the Colorado Plateau are given below. More specific and in-depth information on arid and semi-arid landforms may be found in Smith 1968, Peterson 1981, and Howard and Mitchell 1985. Landform data are recorded by circling the proper choice. Record the position of the sample site in relation to the landform(s). Indicate by circling the appropriate term:

***Rockpile***

Uplands composed primarily of jointed and exfoliating granitic outcrops so that separate blocks are demarcated which tend to have semispheroidal surfaces. In the aggregate, such rockpiles resemble heaped up sacks of wool (Smith 1968).

***Bajada***

Coalesced alluvial slopes or fans (colluvium) which accumulate at the base of a desert mountain and are interrupted by the trenching of minor watersources. Sometimes referred to as a pediment. Alluvial fans generally form at the mouths of desert mountain canyons. Large fans manifesting from adjacent canyons coalesce to form a bajada. The composition of the fans change from the base (finer particles) to the head (coarser).

***Drainage Channel***

Bottom (not side slope) of a drainage confined by banks or a canyon.

***Valley Bottom Fill***

Usually level (or nearly level) places where alluvium collects at the bottom of bajadas, i.e., bolsons or valley bottoms; may include floodplains (the more or less level outwash from one or more drainage channels subject to periodic inundation).

*Playa*

A Pleistocene lake bed, now dry, but often with some surface water, such as the Death Valley Playa; typically the bed is composed of a hard, clay surface; a salt crust is often present, but the soils, in any case, are generally saliniferous. Vegetation, when present, is dominated by halophytes.

*Side Slope*

Sides of drainage channels. Where the slope is relatively remote from the channel, use lower, mid, or upper slope designations.

*Lower Slope*

The lower and (usually) better watered portion of a slope (if near a drainage, see "Side Slope").

*Mid Slope*

The central portion of a slope (including drainage channels).

*Upper Slope*

The upper and (usually driest) portion of a slope (including drainage channels).

*Interfluve*

The area between small drainage channels (cf. "Ridge").

*Ridge*

High ground between two opposing slopes (often but not always associated with major drainage channels), or the crest of block-faulted mountains.

*Slick Rock*

Large exposed expanses of bedrock (usually sandstone, but may be granite or other material) which is generally monolithic, smooth, but often punctuated with potholes, and either barren or supporting sparse vegetation.

*Terrace*

Level or gently sloping shelf perched on a slope; often caused by receding lake shores or down-cutting rivers. In sedimentary rockpiles, terraces may be perched on erosion resistant rock strata.

*Mesa*

Level or gently sloping ground surrounded on 3 or more sides by steep down slopes and capped with a resistant rock layer.

*Butte*

Similar to a mesa, except that the top is some configuration other than flat or, if flat, is extremely reduced in extent.

*Cliff*

Very steep rock slopes, often with waterfalls, hanging gardens, etc.

*Talus*

Unsorted material resulting from mass wasting of steep mountain slopes.

*Sand Dune/Sand Sheet*

Large accumulations of sand, may be stable or unstable (moving); generally sparsely vegetated.

### Parent Material

Record parent material (the unconsolidated organic and mineral material in which soil forms (for example, limestone or sandstone [Taylor 1980:112]) by circling the best choice:

*Alluvium*

Rock type not evident or bedrock not locally exposed. Clay, silt, sand, gravel, or similar detrital material deposited by running water.

*Colluvium*

Rock detritus and soil accumulated at the foot of a slope.

*Igneous Extrusive*

Rhyolite, Basalt, Tuff, Cinders.

*Igneous (plutonic)*

Granite, Diorite, and other crystalline types.

*Metamorphic Rock*

Gneiss, Schist, Marble, Slate, Serpentine.

*Sedimentary Rocks*

Sandstone, Conglomerate, Shale, Limestone.

### Land Use Data

Record land use adjacent to the relevé by circling the appropriate term(s). Wasteland is unoccupied disturbed ground such as abandoned fields, timber clear cuts, fresh earth fill, etc.

## Vegetation Relevés

### Species Prominence

Prominence value is a rating that combines estimated dominance, biomass, and commonness. Prominence values are the most important part of vegetation description for classification and mapping. Sample the vegetation (with emphasis on prominence values) several times in each of the landscape-terrain features in the geographic area.

### Record Plants Present

*Presence*

Begin your observations by walking around the sample site, recording names of plant species present either in the column labelled "Name" or "α-Code" on the face of the CPVAC Vegetation

Record form. If needed, additional space is available on the back. Record all perennial species, including grasses, and all common annual plants. At this point take some time walking around the sample site to form impressions about clumpiness of plant distribution, rockiness of the soil, fire, history, disturbance, etc. The 4-letter codes are for convenience. These codes, often referred to as "alphacodes," are commonly used by the Forest Service, Bureau of Land Management, and other Federal agencies. The Soil Conservation Service (SCS 1982) has a standardized list of plant species and alphacodes. Other standard lists are also available. However, as taxonomists change species name, such lists will become superannuated. It is more practical to form your alphacodes using the first two letters of the genus to which is appended the first two letters of the species. If a variety or subspecies is involved, then the first letter of this epithet is appended onto the first four. Thus *Pinus ponderosa* ssp. *scopulorum* becomes PIPOS. Should two species have the same alphacode (a not uncommon occurrence), a number which follows the actual alphabetical sequence of the original binomial is appended to the 4-letter prefix as a suffix. For example: *Artemisia biennis* and *Artemisa bigelovii* are rendered as ARBI1 and ARBI2 (alternatively, ARBI-1 and ARBI-2), respectively. If, for whatever reason, you are concerned about ambiguity with respect to a certain species' alphacode, use a six-letter code or other reasonable contingency to ameliorate the problem. Upon completion of the project, a conversion table of alphacodes and species names, along with notes on any ambiguities and how these were resolved, should be prepared and placed in the files with the original documentation as well as in any report which results from the project.

#### *Collection and Identification*

Collect specimens of any plants whose identity is not certain (see Appendix II for directions). If you make a collection, either write "Y" or use your plant collection number in the column labelled "Coll."

### Record Prominence Values

Assign a prominence value to each species on a scale of 1 through 5. Record the results in the appropriate column.

5 = Dominant. - Uniformly distributed throughout stand; clearly the one single dominant species.
4 = Co-dominant. - Uniformly distributed throughout stand; shares dominance with other species.
3 = Associate. - Common throughout stand, but not dominant; easily observed everywhere in stand.
2 = Uncommon. - Sparse; represented by few individuals (≅2-12) with coverage usually < 1%. Requires searching stand to find; may be erratically distributed.
1 = Rare. - Represented by very few individuals (≅1-2); requires searching to find.

### Dispersion (Sociability)

Two species with the same prominence values may be distributed quite differently in the community. The method used to determine the "dispersion" of individual plant species is taken from Braun-Blanquet (1932) who established the following five point scale:

5 = growing in large almost pure population stands (e.g., *Coleogyne*, some *Larrea* stands)
4 = growing in small colonies or forming larger carpets (e.g., *Bouteloua gracilis* and other mat and turf-forming grasses)
3 = forming large patches or cushions (e.g., *Petrophytum caespitosum*)
2 = forming clumps or dense groups (e.g., many bunch-grasses like *Deschampsia caespitosa* and *Stipa* spp.).
1 = growing solitarily (e.g., some spp. of *Mammilaria* or *Coryphantha*)

## Dominance Summary

Record, as time permits, vegetation data of ancillary importance used to describe the appearance and arrangement of the plant community. Write these data in the columns on the back of the CPVAC Vegetation Record form.

### Plant Height

Estimate greatest, average, and least height of each synusium (dominant tree, codominant tree, dominant shrub, codominant shrub, forbs, graminoids, annual herbs, moss, and litter layers). Actual height measurements are not needed, but see Figure 2 for directions if you need to check yourself. A clinometer, Abney level, or any instrument capable of giving inclinations and declinations in either percent or degrees can be used to estimate heights. The height codes (Table 3) are found at the bottom of the back of the form.

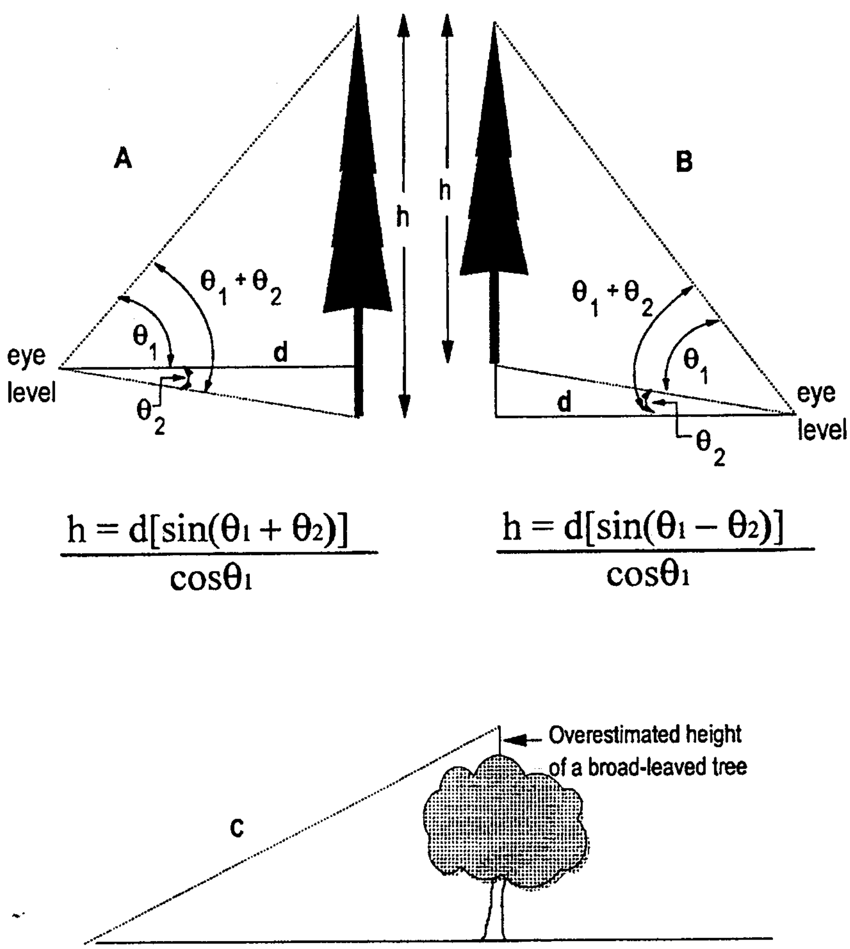
### Cover Percentage

Estimate percentage of the community area covered by plants rooted in the substratum, as seen from above, and record coverage of each synusium (dominant tree, codominant tree, dominant shrub, codominant shrub, forbs, graminoids, annual herbs, moss, litter, bare layers). Each layer can total 100 percent cover. Use these codes which also appear on the back of the form. The scale (Table 4) is based on a modified Braun-Blanquet (1932 ) system. Record the

Table 3. Table of vegetation/species height class codes.

| CODE | METERS[1] | FEET[2] |
|---|---|---|
| 6 | 30+ | 98.4+ |
| 5 | 8-30 | 26.2-98.4 |
| 4 | 2-8 | 6.6-26.2 |
| 3 | 1-2 | 3.3-6.6 |
| 2 | 0.3-1 | 1.0-3.3 |
| 1 | 0-0.3 | 0-1.0 |

[1] The first four categories are based on Raunkiaer's (1934) discrimination among Mega-, meso-, micro- and nanophanerophytes, respectively.
[2] Measurements should be recorded in meters. English equivalents are given for reference and convenience only.




$$h = \frac{d[\sin(\theta_1 + \theta_2)]}{\cos\theta_1}$$

$$h = \frac{d[\sin(\theta_1 - \theta_2)]}{\cos\theta_1}$$

*Figure 2. Trigonometric method for measuring tree heights when (A) eye level is above the tree base; (B) eye level is below the tree base. Notice that the height of broad-crowned deciduous trees (C) is generally overestimated.*

Table 4. Modified Braun-Blanquet (1932) vegetation cover rating system.

| VERBAL DESCRIPTION | COVER CLASS | CODE |
|---|---|---|
| Species absent from plot | 0% | 0 |
| Few individuals, cover < 1/100 of plot | 0%<X<1% | 0.1 |
| May be numerous, but cover < 1/20 of plot | 1%<X<5% | 1 |
| Any number of individuals, cover 1/20 - 1/4 of plot | 5%<X<25% | 2 |
| Any number of individuals, cover 1/4 - 1/2 of plot | 25%<X<50% | 3 |
| Any number of individuals, cover 1/2 - 3/4 of plot | 50%<X<75% | 4 |
| Any number of individuals, cover > 3/4 of plot | 75%<X<100% | 5 |

answer in the column labelled "Cover." Workers may check their estimates against a line intercept (see Appendix IV).

## Classification Summary

### Relevé Summary Table

Complete the Relevé Summary Table form provided. Complete a summary tabulation table at the end of the day while your recollections are fresh. Place 4-letter plant alphacodes in the α-codes column and relevé number across the top. Enter prominence values in the body of the table according to species and relevé. Indicate missing plants, which of course have no prominence values, by leaving them blank. Calculate the arithmetic mean (X) of the prominence values for each plant by dividing the sum of the values by the number of relevés listed across the top page. Missing values (blanks) count as zero. Calculate species frequency (fr) by dividing the number of relevés with each plant by the total number of relevés. Record this number to 1 decimal place on the Relevé Summary Table to the right of the heavy line on the right side of the page.

### Sorted Relevé Summary Table

Enter the plants by their full scientific names or by their alphacodes. First list perennial plants in descending order based on frequency. Where two or more plants have the same frequency, list them in descending order based on their mean prominence values. Annual species will be listed later.

Draw a line across the page separating plants whose frequencies are >0.5 from those ≤0.5. These are the character species used to name the vegetation type. Draw another line across the page separating the plants with frequencies >0.1 from those whose frequencies are ≤0.1. These are the accessory species.

List annual species by their full scientific names or by their alphacodes. First list annual plants in descending order based on frequency. Where two or more plants have the same frequency, list them in descending order based on their mean prominence values.

Save and file the original field form. The original is the primary record; do not discard it.

### Field Classification

Make your best estimate of a SRFR vegetation type based on most recent classification. If your data does not seem to fit the classification, DO NOT FORCE IT. You may have found a new vegetation type. Make a note that it does not fit well and continue. Field classification is important because it describes what was seen in the field and is useful to the classifier in the office. Mail the Sorted Relevé Sheet and copies of relevant filed forms to the CPVAC. The final classification will be made by the committee following further data analysis.

Finally, plant community classification is not a by-the-book mechanical process—there are principles, but not rules—classifiers in the field are expected to, and must be prepared to, deal with uncertainty.

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# APPENDIX I: A PRELIMINARY VEGETATION CLASSIFICATION FOR THE COLORADO PLATEAU[1]

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## ABSTRACT

A new vegetation classification is developed and applied to the Colorado Plateau. Termed the SRFR classification, it is loosely based on the Brown, Lowe and Pase system. The SRFR classification is hierarchical and open-ended and can be adapted to any region of North America. The levels in the hierarchy, from broad scale to fine scale, are biogeographic realm, floristic province, climate-elevation zone, plant formation, series, and association. A preliminary classification of the vegetation of the Colorado Plateau is presented to the series level.

## INTRODUCTION

This report examines vegetation classification in the region of the Intermountain West known as the Colorado Plateau, as it is defined physiographically by Hunt (1967) and floristically by McLaughlin (1989). After a preliminary review of various classifications, some of which have been used or suggested for the region, the bulk of the report will concentrate on a new vegetation classification which is based in part on the Brown, Lowe and Pase (1980) classification (henceforth BLP). We provide a preliminary classification of the vegetation on the Colorado Plateau to the series level, and present criteria and methods for classification of field data.

## LITERATURE REVIEW

Classification of vegetation can be done at various scales of resolution. The detailed classifications of the U.S. Forest Service habitat and community types are an example of a very fine level of resolution. Forest vegetation is classified by series and habitat-community types (=associations), but is not incorporated into an explicit higher-level classification. Above the level of series several world and North American vegetation classifications have been applied, or could potentially be applied, to the Colorado Plateau. These include *inter alia* the classifications of Fosberg (1961), Holdrige (1967), Kuchler (1964), UNESCO (1973), and BLP (1980; also Brown 1982). Other, less widely used systems exist as well (e.g., Dansereau 1957; Krajina 1965). All these classifications vary greatly in the criteria used in their construction. Primary plant criteria include flora, physiognomy (structure), function, dynamics, and biogeography. Some are "pure" plant-based classifications, while others incorporate climate and elevation. Published work using at least three of the above criteria exist for portions of the Colorado Plateau, BLP (BLP 1980), Holdrige (MacMahon and Wieboldt 1979; MacMahon 1988), and Kuchler (1964; see also MacMahon 1988, West 1988).

The classification of Fosberg (1961) is simple, hierarchical, and predominantly plant-based. The main features used are dominant life-form (tree, shrub, herb, etc.) and density (spacing, e.g., open, closed). It is somewhat cumbersome because of the large numbers (31) of formations. Also, some of the differences between formations appear to be arbitrary (e.g., scrub savanna vs. low savanna).

The floristic classification of Kuchler (1964) has been widely applied in the U.S. (e.g., Barbour and Major 1988, West 1988). There are many vegetation types (mapping units), and it is non-hierarchical. Potential natural vegetation rather than actual vegetation is used. The primary criterion used is floristic (the dominant species present).

Holdrige (1967) developed a classification based on life-zones, controlled by latitude, elevation, and climate. Each unique combination of biotemperature, precipitation, and evapotranspiration, describes a particular life-zone that is reflected in a particular kind of vegetation. The vegetation terms are largely structural-functional (i.e., steppe, desertscrub). A great deal of climatic information is needed to apply this system to a region. MacMahon and Wieboldt (1979; see also MacMahon 1988) have applied the classification to Utah.

The UNESCO system uses a hierarchical classification of primarily physiognomic features, within floristic provinces (UNESCO 1973; in Mueller-Dombois & Ellenberg 1974). Forest, woodland, shrubland, and grassland are characteristic formations, with finer groupings detailed based on height, leaf size, and leaf duration. Some non-plant features are incorporated, but fewer than many systems. This classifications has been extensively used and is world-wide in scope.

The BLP system (Brown 1982) incorporates vegetation, flora, topography, and climate. It is the most explicitly hierarchical and open-ended of the systems detailed. Although used primarily in the western U.S., the system may be adaptable to the world level, as noted in BLP (1980). This system is the one chosen for use in National Park Service units on the Colorado Plateau (Spence 1993). Spence (1992) has analyzed the structure of the BLP system with reference to the Colorado Plateau.

We have found that the BLP system as it currently stands is inadequate to classify the vegetation of the Colorado Plateau. In particular, several problems were encountered that required solutions before the classification could be applied to the Colorado Plateau. Below, we examine these problems within each of the levels in the BLP hierarchy, and discuss our solutions.

## UPLAND-WETLAND

Vegetation occurs across a continuum of moisture availability, and although the endpoints may be distinct, any attempt to differentiate wetlands and uplands is arbitrary. We feel that classifying vegetation into these categories is both unnecessary and redundant. The plants themselves, especially at the formation and series levels, already reflect site differences in available moisture. The upland-wetland level is dropped in our classification.

## FORMATION

Formations are traditionally named after the physiognomy of the vegetation, e.g., forest, grassland, etc. However, in the BLP system logically unrelated concepts are mixed together. Two formations are climate-landscape terms (tundra and desertland), while the rest are true plant structural-formations (e.g., forest, grassland). This produces some problems in classification, e.g., grass dominated vegetation could be classified under both grassland and tundra. We have removed tundra from the system, as tundra vegetation can be classified as shrubland, grassland, or forbland.

The BLP formation desertland (sometimes also called desertscrub) is redefined and named thornscrub. Subtropical and tropical arid thornscrub vegetation, consisting of drought deciduous thorny trees and large succulents, is very different in origin, function, and structure from the simpler shrublands and forests in the southwestern U.S. and Mexico (cf. Brown 1982).

Two formations have been added, tall and low shrublands, based on height and growth form of shrubs. Tall shrubland is equivalent to scrub in the BLP system. Low shrubland was necessary in order to classify some shrub vegetation on the Colorado Plateau. In the original BLP system, shrub vegetation was classified under either scrub (=tall shrubland) or desertland (=desertscrub). However, much low shrub vegetation on the Colorado Plateau and elsewhere in western North America is neither scrub nor desertland.

In order to classify certain communities on the Colorado Plateau, a formation which represented broad-leaved forbs, both annual and perennial, was needed. This vegetation consisted of certain subalpine forb communities (very common in the central-northern Rockies) dominated by, *inter alia*, *Lupinus*, *Mertensia*, various Asteraceae, *Thalictrum*, etc., and in which grasses are generally unimportant, and also certain badland communities on heavy clays and shales dominated by annual species of *Atriplex*, *Eriogonum* and *Phacelia*. We have added a forbland formation to the classification. Formations are defined below.

### Forest and Woodland

Vegetation dominated by trees (usually or potentially >10 m in height). Forests have closed (interlocking or touching) canopies whereas woodlands have open canopies.

### Thornscrub

(=desertscrub or desertland of BLP in part). Tropical-subtropical arid land formation dominated by a mix of microphyllous trees and shrubs, and tall succulents, often spiny or thorny (e.g., as in Sonoran desert).

### Savanna

Tropical-subtropical formation of grasses with a very open canopy of widely spaced trees, dominated by tall seasonal grass layer. Does not occur on the Colorado Plateau.

**Tall Shrubland**

(=scrub of BLP). Vegetation dominated by shrubs, mostly <5 m in height, usually multi-stemmed, open (shrubland/scrub) or densely interlocked (thickets). In many parts of the world this is traditionally called scrub.

**Low Shrubland**

(=desertscrub or desertland of BLP in part). Vegetation dominated by woody, single or multi-stemmed dwarf or mat shrubs that are generally <1 m in height.

**Grassland**

Vegetation dominated by perennial or annual species of grasses.

**Marshland**

Vegetation dominated by herbaceous obligate wetland species of sedges, rushes, cattails, etc.

**Forbland**

Vegetation dominated by herbaceous perennial and annual species of broad leaved ferns, dicots or non-graminoid monocots (e.g., lilies, irises).

**Aquatic**

Vegetation dominated by herbaceous species that are supported by water and are either rooted, their structures underwater or floating on the surface, or plants free-floating on the surface.

**Cryptogamic**

Vegetation dominated by cryptogams, either lichens or bryophytes (includes sphagnum bogs).

**Nival**

Permanent snow and ice with some exposed rock, dominated by cryptogams, with vascular plants rare. Does not occur on the Colorado Plateau.

**Barren**

Areas essentially bare of vegetation. These can include salt barrens, shale barrens or slickrock. Plants can be present, but occur only as scattered individuals with very low cover.

## CLIMATIC ZONE

The climatic zonation used in BLP is difficult to apply to the Colorado Plateau, as it does not properly reflect the complexity of climate-controlled vegetation zonation. Two aspects of climate need to be considered, regional climate and orographic effects. For regional climate, Walter (1985) provides a useful classification, with two zonobiomes in the region, subtropical-arid, and arid-temperate with cold winters. Although there are latitudinal and longitudinal differences in climate on the Colorado Plateau at similar elevations, orographic effects predominate. The division of BLP zones into boreal-arctic, cold and warm temperate, and subtropical is largely controlled by elevation on the Colorado Plateau and in the southwestern U.S. in general. We have re-drawn the climate zones as elevationally controlled zones, based largely on traditional zonation schemes. These zones are shown in Table 1, with defining and controlling factors identified. Climate zonation remains difficult to use because it can vary locally depending on aspect and topography. We have

**Table 1.** Elevational limits and controlling factors of climate-elevation zones defined for the Colorado Plateau.

| Zone | Elevational Limits | Controlling Factors |
|---|---|---|
| Alpine | Upper: 3862 m<br>Lower: 3440-3600 m | highest point on plateau<br>snowpack, cold air drainage |
| Subalpine | Upper: 3440-3600 m<br>Lower: 2750-3050 m | 50° July isotherm, wind<br>fire? |
| Montane | Upper: 2700-3100 m<br>Lower: 1900-2700 m | winter snow, temperature?<br>drought (arid/humid boundary) |
| Submontane/Cold-temperate Lowland | Upper: 1900-2200 m<br>Lower: 900-1200 m | competition, winter temperatures<br>summer temperatures, drought |
| Warm-temperate Lowland | Upper: 900-1500 m | winter temperatures |

drawn zonal boundaries broadly, and provide vegetation criteria (Tables 2-3) that will help in identifying each zone. As climate data are scarce for much of the Colorado Plateau, no attempt is made here to provide climatic definitions and characteristics for each zone. Some zonal boundaries remain poorly understood, e.g., the montane-subalpine boundary. Also, riparian vegetation, as it consists of linear strips cutting across zones, will be more difficult to place into zones than most other kinds of vegetation. Future work addressing these problems, and also in providing a climatic characterization for each zone, is needed.

We recognize that vegetation rarely occurs as discrete elevational bands on the Colorado Plateau. An alternative system could be envisioned in which landscape "elements" (based on

**Table 2.** Characteristic vegetation features and species on upland or dry sites for each climate-elevation zone on the Colorado Plateau.

| Zone | Vegetation | Characteristic Species |
|---|---|---|
| Alpine | meadows<br>fell-field | *Silene acaulis*<br>*Acomastylis rossii*<br>*Erigeron vagus* |
| Subalpine | coniferous forest | *Abies bifolia*<br>*Picea engelmannii*<br>*Pinus longaeva* |
| Montane | coniferous forest<br>montane scrub | *Pinus ponderosa*<br>*Abies concolor*<br>*Pseudotsuga menziesii*<br>*Cercocarpus ledifolius*<br>*Quercus gambelii*<br>*Acer grandidentatum*<br>*Juniperus scopulorum*<br>*Artemisia nova*<br>*Populus tremuloides* |
| Submontane/Cold-temperate Lowland | pinyon-juniper woodland<br>semi-arid shrubland<br>galleta-three awn steppe | *Pinus edulis*<br>*Juniperus osteosperma*<br>*Artemisia tridentata*<br>*Atriplex confertifolia*<br>*Coleogyne ramosissima*<br>*Hilaria jamesii*<br>*Stipa comata* |
| Warm-temperate Lowland[1] | desertscrub | *Larrea divaricata*<br>*Acacia greggii*<br>*Encelia farinosa*<br>*Ferrocactus sp.*<br>*Yucca brevifolia*<br>*Fouquieria splendens* |

[1] This zone does not occur on the Colorado Plateau *per se*. However, some component species do occur in closely adjacent areas, such as in extreme western Grand Canyon National Park, and penetrate some distance (Havasu Creek) into the Plateau along the Colorado River Corridor.

Table 3. Characteristic vegetation features and species in wetland sites for each zone on the Colorado Plateau.

| Zone | Vegetation | Characteristic Species |
|---|---|---|
| Alpine | No Data Available | |
| Subalpine | fen, carr[1] | *Salix glauca* |
| Montane | marshland<br>riparian forest and scrub | *Populus angustifolia*<br>*Alnus tenuifolia*<br>*Cornus stolonifera*<br>*Salix boothii*<br>*S. geyeriana* |
| Submontane/Cold-temperate Lowland | marshland<br>riparian forest and scrub<br>hanging garden | *Acer negundo*<br>*Populus fremontii*<br>*Salix exigua*<br>*Cirsium rydbergii*<br>*Primula specuicola*<br>*Mimulus eastwoodiae* |
| Warm-temperate Lowland | mesquite bosque<br>riparian forest and scrub | *Prosopis glandulosa*<br>*Fraxinus pennsylvanica*<br>*Juglans major*<br>*Platanus wrightii*<br>*Baccharis sarothroides* |

[1] Low lying wetland willow complexes at high elevations.

topography, elevation, soils, etc.) are the building blocks of a vegetation classification. However, such a system would be far more difficult to use because of its greatly increased complexity. Climate-elevation zones, although less realistic, provide a necessary tradeoff between accuracy of vegetation classification and practicality.

## BIOME

There are many definitions of biomes, but one (Whittaker 1975) is "a major plant community, with associated animals, as recognized by physiognomy". Whittaker's list of North American biomes is instructive; broad-leaved deciduous forest, grassland, tundra, coniferous forest, etc. Clearly these are very close to the definition of the formation in the BLP system, differing largely in the inclusion of animals in the biome, and generally also by incorporating some geographic restrictions and associated climate (e.g., temperate). In the BLP system, the biome appears to be somewhat narrower [compare "Rocky Mountain subalpine conifer forest" (BLP) with "temperate evergreen forest" (Whittaker 1975)].

The last 30 years of paleoecological research (e.g., Betancourt et al. 1990) in the southwest has completely invalidated the Clements-Weaver biome concept, i.e., a co-evolved vegetation unit with a center of origin migrating in unison. Because of the problems with definition of the biome, and the unfortunate connotations of the name itself, we have completely revised this level. Rather than use the biome concept, we have decided to use floristic provinces. We are impressed by the statistically robust and intensive floristic analyses of McLaughlin (1986, 1989, 1992). Our classification uses his subprovinces (but names them provinces for convenience).

McLaughlin recognized a distinct Colorado Plateau unit which he named the Colorado Plateau subprovince of the Intermountain Province. The province level in our new classification logically follows biogeographic realm in the hierarchy, so it is placed second. We prefer to use his subprovinces rather than provinces because the former are more likely to conform to climatic, physiographic, or geological classifications in use in the west (e.g., Hunt 1967). Also, any extensions of McLaughlin's system to other parts of North America could produce changes in the higher levels in his hierarchy. His subprovinces comprise the lowest, fundamental building blocks of his system and should remain unaffected by more extensive analyses.

## SERIES

The series is a widely used term throughout the western U.S., as used by the U.S. Forest Service in their extensive vegetation classifications. It is defined and named by the dominant species or codominants, if more than one occur, in a community. Currently, no specific set of rules have been formulated for defining a series. We have incorporated published series from a wide variety of sources into our classification.

## ASSOCIATION

Associations have traditionally been difficult to define, and we do not attempt to provide one here. However, there is a consistent method available of naming them (e.g., the U.S. Forest Service). The name is based on the dominants in all recognizable important strata. For example, under ponderosa pine series are the following associations (community/habitat types sensu U.S.D.A. Forest Service): *Pinus ponderosa/ Muhlenbergia virescens, P.p./Festuca arizonica, P.p./ Arctostaphylos pungens*, etc. (Hanks et al. 1983). Although the emphasis on classifying Colorado Plateau vegetation is not on the association, this method of recognizing and naming associations is probably the best system to use in order to prevent confusion with other work, and to be consistent with classifications of the U.S. Forest Service.

## THE SPENCE/ROMME/FLOYD-HANNA/ROWLANDS (SRFR) CLASSIFICATION

The classification presented here differs in several respects from the BLP system, although they share strong philosophical and logical similarities. We feel that it is inappropriate to continue to use the BLP name and have simply used the first letters of our names, SRFR, to name the new classification.

The hierarchical structure of the SRFR system is presented below. Each letter in the series ABCDEF.GHIJ is associated with one of the six levels in the hierarchy. In actual named vegetation, the letters are replaced by numbers, hence the sequence 101201.01 represents the *Picea engelmannii-Abies bifolia* series in the subalpine zone, forest and woodland formation, on the Colorado Province in the Nearctic realm (no association is indicated).

A = Biogeographic realm (1 for Nearctic realm; not shown in classification)
B = Floristic Province (first number in sequence; 01 as more than 10 provinces exist)
D = Climate-elevation zone
EF = Plant Formation
GH = Series (first two numbers to right of decimal)
IJ = Association

A preliminary classification of the Colorado Plateau to the series level is presented in Table 4. This listing highlights the many gaps in our knowledge of the vegetation on the Colorado Plateau. In particular, high elevation treeless vegetation, and wetlands, are poorly understood.

Table 4. Preliminary SRFR vegetation classification for the Colorado Plateau. Numbers without designated series are available for the incorporation of new series.

01 COLORADO PLATEAU PROVINCE (0 not listed below)

11 Alpine zone (>3440 m)

1101 Grassland formation
- 1101.01 *Carex elynoides* series
- 1101.02 *Festuca ovina* series
- 1101.03

1102 Forbland formation
- 1102.01 *Erigeron vagus* series
- 1102.02 *Acomastylis rossii* series
- 1102.03

1103 Low shrubland formation
- 1103.01

1104 Marshland formation
- 1104.01

1105 Aquatic formation
- 1105.01

1106 Barren formation
- 1106.01

12 Subalpine zone (2750-3600 m)

1201 Forest and woodland formation
- 1201.01 *Picea engelmannii-Abies bifolia* series
- 1201.02 *P. engelmannii* series
- 1201.03 *A. bifolia* series
- 1201.04 *Populus tremuloides* series
- 1201.05 *Pinus longaeva* series
- 1201.06

1202 Tall shrubland formation
- 1202.01

1203 Low shrubland formation
- 1203.01 *Juniperus communis* series
- 1203.02 *Ribes montigenum* series
- 1203.03 *Potentilla fruticosa* series
- 1203.04 *Salix wolfii* series
- 1203.05

1204 Grassland formation
- 1204.01 *Festuca ovina* series
- 1204.02 *F. thurberi* series
- 1204.03

1205 Marshland formation
- 1205.01

1206 Forbland formation
- 1206.01

1207 Aquatic formation
- 1207.01

1208 Barren formation
- 1208.01

13 Montane zone (1900-3100 m)

1301 Forest and woodland formation
- 1301.01 *Pseudotsuga menziesii* series
- 1301.02 *Abies concolor* series
- 1301.03 *Pinus ponderosa* series
- 1301.04 *P. flexilis* series
- 1301.05 *Populus tremuloides* series
- 1301.06 *Juniperus scopulorum* series
- 1301.07 *Picea pungens* series
- 1301.08

1302 Tall shrubland formation
- 1302.01 *Cercocarpus ledifolius* series
- 1302.02 *Quercus gambelii* series
- 1302.03 *Amelanchier utahensis* series
- 1302.04 *Robinia neomexicana* series
- 1302.05 *Chrysothamnus nauseosus* series
- 1302.06 *Betula occidentalis* series
- 1302.07 *Alnus tenuifolia* series
- 1302.08 *Cornus stolonifera* series
- 1302.09 *Salix boothii* series
- 1302.10 *Salix bebbiana* series
- 1302.11

1303 Low shrubland formation
- 1303.01 *Artemisia nova* series
- 1303.02 *Purshia tridentata* series
- 1303.03 *Arctostaphylos patula* series
- 1303.04

1304 Grassland formation
- 1304.01 *Poa fendleriana* series
- 1304.02

1305 Marshland formation
- 1305.01 *Eleocharis palustris* series
- 1305.02

**Table 4,** *continued*

1306 Forbland formation
- 1306.01 *Pteridium aquilinum* series
- 1306.02 *Eriogonum panguicense* series
- 1306.03

1307 Aquatic formation
- 1307.01

1308 Barren formation
- 1308.01

14 Submontane/cold temperate lowland zone (900-2200 m)

1401 Forest and woodland formation
- 1401.01 *Pinus edulis* series
- 1401.02 *Juniperus osteosperma* series
- 1401.03 *J. monosperma* series
- 1401.04 *Populus angustifolia* series
- 1401.05 *P. fremontii* series
- 1401.06 *Salix goodingii* series
- 1401.07 *Acer negundo* series
- 1401.08 *Elaeagnus angustifolia* series
- 1401.09 *Ostrya knowltonii* series
- 1401.10

1402 Tall shrubland formation
- 1402.01 *Artemisia tridentata* series
- 1402.02 *Quercus gambelii* series
- 1402.03 *Sarcobatus vermiculatus* series
- 1402.04 *Tamarix ramosissima* series
- 1402.05 *Salix exigua* series
- 1402.06 *Amelanchier utahensis* series
- 1402.07

1403 Low shrubland formation
- 1403.01 *Coleogyne ramosissima* series
- 1403.02 *Artemisia spinescens* series
- 1403.03 *A. pygmaea* series
- 1403.04 *A. filifolia* series
- 1403.05 *Eurotia lanata* series
- 1403.06 *Atriplex confertifolia* series
- 1403.07 *A. canescens* series
- 1403.08 *A. corrugata* series
- 1403.09 *A. gardneri* series
- 1403.10 *Ephedra viridis* series
- 1403.11 *Grayi brandegei* series
- 1403.12 *Poliomintha incana* series
- 1403.13 *Gutierrezia sarothrae* series
- 1403.14 *Vanclevea stylosa* series
- 1403.15 *Eriogonum corymbosum* series
- 1403.16 *Fallugia paradoxa* series
- 1403.17 *Quercus harvardii/undulata* series
- 1403.18 *Parryella filifolia* series
- 1403.19 *Toxicodendron rydbergii* series
- 1403.20

1404 Grassland formation
- 1404.01 *Hilaria jamesii-Aristida purpurea* series
- 1404.02 *Stipa hymenoides* series
- 1404.03 *S. comata* series
- 1404.04 *Hilaria jamesii* series
- 1404.05 *Bouteloua gracilis* series
- 1404.06 *Sporobolus cryptandrus-S. contractus* series
- 1404.07 *S. airoides* series
- 1404.08 *Bromus tectorum* series
- 1404.09 *Distichlis spicata* series
- 1404.10 *Elymus salinus* series
- 1404.11 *Calamovilfa gigantea* series
- 1404.12 *Phragmites australis* series
- 1404.13

1405 Marshland formation
- 1405.01 *Typha latifolia* series
- 1405.02 *T. domingensis* series
- 1405.03 *Scirpus pungens* series
- 1405.04 *S. validus* series
- 1405.05 *S. acutus* series
- 1405.06 *Juncus arcticus* series
- 1405.07 *Eleocharis palustris* series
- 1405.08 *Cyperus erythrorhizos* series
- 1405.09 *Carex nebrascensis* series
- 1405.10

1406 Forbland formation
- 1406.01 *Adiantum capillus-veneris* series
- 1406.02 *Cleomella palmeriana* series
- 1406.03 *Eriogonum flexum* series
- 1406.04 *E. inflatum* series
- 1406.05 *Salsola australis* series
- 1406.06 *Melilotus officinalis* series
- 1406.07 *Solidago occidentalis* series
- 1406.08 *Oxytenia acerosa* series
- 1406.09

1407 Aquatic formation
- 1407.01 *Zanichellia palustris* series
- 1407.02

1408 Barren formation
- 1408.01 *Cercocarpus intricatus* series
- 1408.02 *Xylorhiza tortifolia* series
- 1408.03

## HOW TO CLASSIFY VEGETATION

Once vegetation data is collected and analyzed (cf. Rowlands 1994), a series level determination can usually be made. The dominant or two or more dominants (i.e., co-dominants) are used to define the series. After this stage, placement of the series into the classification is usually routine. Three questions that need to be answered are:

1. What is the floristic province? There may be some problems if the site in question is on a province boundary. The best solution is to determine (1) geologically and physiographically, what is the area considered (if known), and (2) what are the floristic affinities of the subdominant herbaceous flora? (Dominant plant species, especially woody species, tend to be widespread and often do not conform to floristic provinces.)

2. In what climate-elevation zone does the vegetation occur? As climatic zonation is highly variable from area to area, problems will be encountered in making a decision. We have attempted to provide boundaries that relate to biologically important limits, such as treeline, the arid-humid boundary, frost free climates, etc. Many plant species, particularly the dominants, generally are limited in distribution by some aspect of climate. Many subdominant species and many animals will also conform to the limits defined by the dominant species. This observation forms the basis for life zone classifications, such as that of, e.g., C. H. Merriam (1890). In Tables 1-3 can be found information helpful in determining the proper climate-elevation zone. Zonal boundaries are broadly drawn, to reflect real differences in climate, available flora, and history in different parts of the Colorado Plateau.

3. To what plant formation does the series belong? Generally this is easy to determine, but there are certain exceptions on the Colorado Plateau. Mixed shrub-grass vegetation, which has traditionally been called shrub-steppe in the U.S., may be difficult to place. If shrubs dominate in terms of cover and biomass, the series can be classified as a shrubland. However, if shrubs are less common than the grasses, the best placement is grassland. Where an even mix seems to occur, a new formation, shrub-steppe, may be needed.

## DISCUSSION

We have defined the vegetational Colorado Plateau as those areas on the geologic-physiographic Colorado Plateau above the elevation of the hot desert flora, as defined principally by the presence of creosote bush, *Larrea divariacata*, although other species could be named (Tables 2 and 3). Along the southwestern and southern edges this elevation varies from 900-1500 m. Boundaries elsewhere are more difficult to determine. To the west and northwest, the High Plateaus section of the Colorado Plateau grades into the Great Basin on its western slopes. The high Uinta Mountains define the northern edge. The eastern and southeastern edges form an indefinite and complex boundary with the central and southern Rocky Mountains. The White Mountains and Mogollon Rim form the boundary between the Colorado Plateau and the Madrean and Sonoran regions to the south. Classification of vegetation into surrounding McLaughlin subprovinces (provinces in SRFR), including the Great Basin, central Rocky Mountains, southern Rocky Mountains, Madrean, and Sonoran, may be more appropriate depending on where the vegetation work is being done.

As the classification of the region into floristic groups is relatively new, little work has been done yet on delimiting floristic province boundaries. We feel that the work of McLaughlin (1992) could provide a useful starting point for fruitful research into the nature of floristic boundaries and the evolution and dispersal of floristic elements. It should be pointed out that the floristic Colorado Plateau is not the same as a Colorado Plateau floristic element. The former is defined by boundaries, albeit not well understood yet, while the latter consists of species that presumably originated on the plateau, but which in many cases extend into surrounding provinces (cf. McLaughlin 1986, 1989). Furthermore, provinces can be fragmented, with more or less intact outlier regions embedded within other provinces. McLaughlin (1992) illustrates this with his central Rocky Mountain subprovince, which includes a large disjunct fragment in northeastern Nevada surrounded by his Great Basin subprovince. On the Colorado Plateau, a likely candidate for disjunction is the La Sal Mountains, which harbor a large number of species at higher elevations characteristic of the central Rocky Mountains.

The problem of disjuncts also occurs at the climate-elevation level in the classification. Relict patches of vegetation occur on the Colorado Plateau well below or above their usual elevational limits. For example, patches of Douglas fir (*Pseudotsuga menziesii*) occur at elevations as low as 1500 m, well within the submontane/cold-temperate lowland zone. Vegetationally, these patches are clearly related to higher elevation montane forests in their composition. It is probable, although not yet been investigated, that these patches occur in microclimates that mimic climates at higher elevations. We suggest that classification of relict communities like these should reflect their origins. In the case of the Douglas fir relicts, we would classify them as montane rather than submontane/cold-temperate lowland communities.

As the classification name (e.g., series, formation names) does not necessarily convey all information about the vegetation, we suggest a series of descriptors that could provide additional information. First, we recommend adding data on the Raunkiaer life-form system (Raunkiaer 1934) for the species in the vegetation classification (shown in Table 5). This system provides information on the functional responses of plant species to climate, and has been widely used throughout the world. For example, the *Pinus ponderosa* series (Table 4, 1301.03) is dominated by megaphanerophytes (Pg) and mesophanerophytes (Pm) whereas the *Artemisia tridentata* series (1402.01) is dominated by nanophanerophytes (Pn) and hemicryptophytes (H). Combined with data on leaf duration and size (for at least the dominants), vegetation cover, landforms, soils, and other physical data, a much clearer picture of the vegetation in question can be obtained.

Several aspects of vegetation classification will need to be addressed in the future. First, a standardized flora list with identification keys for the Colorado Plateau needs to be developed. Second, objective ways of classifying complex vegetation data at the series and association levels will need to be implemented. We recommend the use of relatively objective multivariate classification and ordination techniques (Causton 1988) for vegetation classification work at or below the series level. Such techniques are readily available as commercial software and take the form of either divisive, polythetic (e.g., TWINSPAN, developed by Hill 1979) or various agglomerative, polythetic methods (e.g., the several forms of cluster analysis described in Pielou 1984). Finally, until research on floristic boundaries is done, a set of rough guidelines, based on characteristic vegetation series or floristic criteria, will need to be developed so that these boundaries can be determined for classification of vegetation.

The SRFR classification should be adaptable to any floristic region in North America, although it may not work at all levels in tropical vegetation (series level classifications are difficult and often impossible to use in the species-rich tropics). Although McLaughlin only analyzed the flora of the western U.S., his techniques and philosophy can be extended to other parts of the country. Currently, enough vegetation work has been done in the U.S. and Canada to formulate climate-elevation zonation for most areas. As our classification is open-ended and flexible, it can be modified to fit most situations that we can foresee elsewhere in North America. Currently, we are adapting the SRFR classification to the central Rocky Mountain region.

Table 5. Suggested Raunkiaer life-form classification (Raunkiaer 1934) for use with the SRFR vegetation classification. Raunkiaer's classification sytem is based on the position of the regenerative parts (perrenating buds) relative to the substrate. With some modification, the codes are based on Dansereau (1957).

| Life-form | Code | Characteristics |
|---|---|---|
| Vascular plants | | |
| Megaphanerophytes | Pg | buds >25 m, large trees |
| Mesophanerophyte | Pm | buds 10-25 m, trees |
| Microphanerophyte | Pp | buds 2-10 m, trees, tall shrubs |
| Nanophanerophyte | Pn | buds 0.5-2 m, shrubs |
| Chamaephyte | Ch | buds >0-0.5 m, dwarf shrubs |
| Hemicryptophyte | H | buds at ground level, forbs, graminoids |
| Geophyte | G | buds buried, bulb forbs |
| Therophyte | Th | annuals |
| Stem succulent[1] | SS | cacti |
| Liana | Li | supported by other plants, rooted in ground |
| Epiphyte | E | on other plants, not rooted in ground |
| Parasite | Pa | parasitic/saprophytic on other plants |
| Hydrophyte | HH | structures supported by water |
| Nonvascular plants[2] | | |
| Lichens | L | lichens (composite alga-fungus) |
| Bryophyte | Br | mosses, liverworts, hornworts |
| Algae | Al | mostly aquatic, includes Chara |

[1]Leaf succulents are included as either chamaephytes or hemicryptophytes by some authors (Mueller-Dombois and Ellenberg 1974).

[2]Nonvascular plants are generally classified into one or more of the above categories as specialized members. For example, Mueller-Dombois and Ellenberg (1974) classify foliose lichens as "thallo-hemicryptophytes" using the abbreviation: Li H fol. For the purposes of this classification system, we recommend a simpler system using the following abbreviations. The interested reader wishing to use a more intensive life-form classification system should consult Mueller-Dombois and Ellenberg (1974).

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# APPENDIX II
# CALIBRATION OF COVER ESTIMATES

## Introduction and Theory

Estimation of ground cover requires experience and occasional calibration of the individual worker against a community whose cover has been determined by the line intercept transect methodology, a technique for quantitatively determining both basal and aerial plant cover area by actual measurement along a randomly oriented straight line. The total length of the plant cover along the line is accepted as a numerical value representing the cover or ground surface occupied by the plants. The method was first described by Tansley and Chipp (1926) and later modified by Canfield (1941) for use in range studies. Lucid descriptions of the line intercept technique are available in Mueller-Dombois and Ellenberg (1974), Bonham (1989), and Brower et al. (1990). In addition, the latter also has well-designed field forms for collection of data including cover, frequency, and relative density. In this instance we are only concerned with vegetation cover.

Vegetation cover estimates can be obtained from a randomly placed line. The line or tape is stretched taut at a height to contact the vegetation canopy. If basal cover is required, the line is placed at ground level. The length of each intercepted plant part is measured (Appendix II, Figs. 1 and 2). Cover (C) is the proportion of the ground occupied by a vertical projection to the ground from the aerial parts of the plant. The length of line and total length intercepted by vegetation are used to estimate percentage cover as well as species cover composition (the percent of total intercept made by individual species). The accuracy of this method is proportional to the accuracy of the vertical projection onto the line. In the case of overstory vegetation. Some sort of sighting device may be required (Bonham 1989, Brower et al. 1990).

In summary, Cover is defined as :

$$C_i = a_i / A_i \qquad (1)$$

where $a_i$ is the total area covered by species $i$ (estimated by basal area, foliage area, or basal coverage) and $A$ is the total habitat area sampled.

The relative coverage ($RC_i$) for species $i$ expressed as a proportion of the total coverage ($TC$) for all species is

$$RC_i = C_i / TC = C_i / \Sigma C, \qquad (2)$$

Where $\Sigma C_i$ is the sum of the coverages of all species (Brower et al. 1990).

Lengths of lines vary; 6-30 m lengths have been used regularly to study vegetation on public lands in the U.S. However lengths of 10, 20, 50 or even 100 m are used to measure vegetation cover in general surveys. The length used depends upon the type of vegetation. In general, cover in herbaceous communities can be estimated with short lines (<50 m) while long lines (>50 m) should be used in some shrub and tree communities. Lines do not have to follow a 180° angle. A 90° angle (half the line perpendicular to the rest of the line) can be used to obtain cover estimates in certain forests (Bonham 1989).

## Equipment Required

The following items are needed:
(1) measuring tape, steel or woven fiberglass, with reel, 25 m or longer or even a similar length of rope or wire;
(2) dowel, hardwood, 3/8 in diameter, 4 ft long;
(3) a sighting device (double right angle prism with center window, Laos/Sokkia or equivalent or a tube with two threads strung across one end as cross hairs—a toilet paper tube or piece of pvc pipe may be adequate);
(4) plumb bob with string;
(5) stakes or chaining pins (several);
(6) line intercept transect forms (Fig. 1) and a clipboard;
(7) ball-point pen or 2.5 hardness pencils; and
(8) a meter stick and 30 cm rule.

This procedure can be done by a single individual, although it is much easier for one person to make the measurements and another to write down the information on the data sheet.

**Method:**

1. Select a sampling site which has been evaluated according to the methods described above

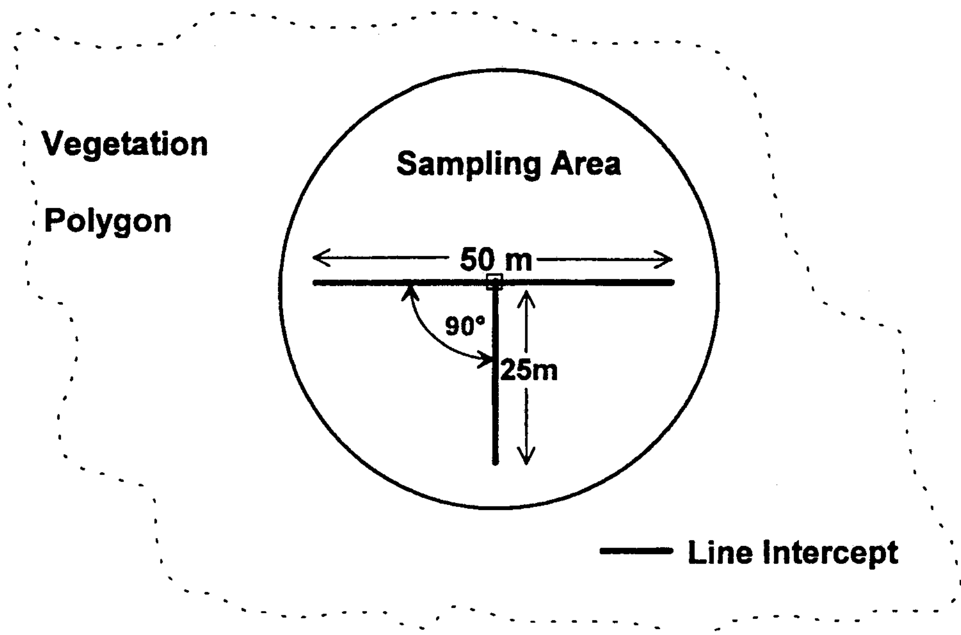


*Figure 1. Diagram of line intercept with alternative 90° angle.*

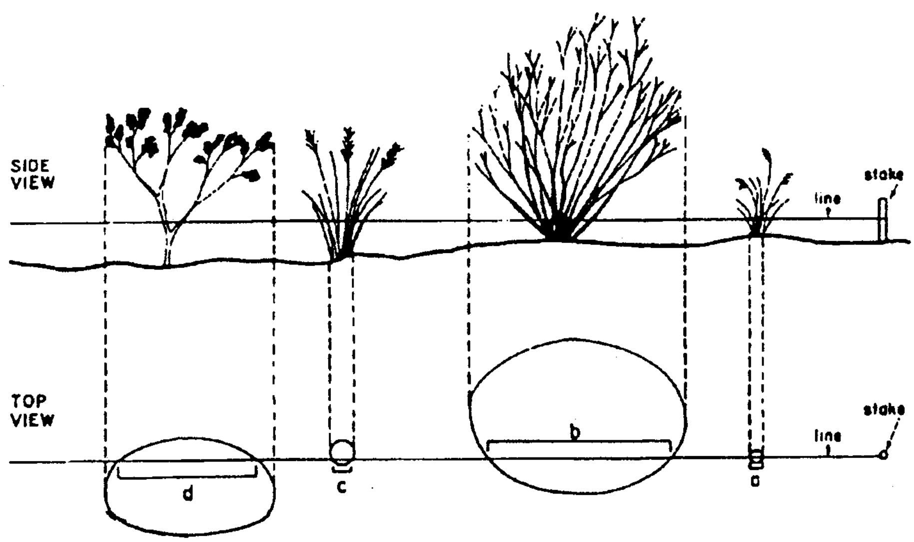


*Figure 2. Diagram of line intercept from above and the side. Figure after Brower et al. (1990).*

and estimate the ground-cover of each species listed in the prominence table. In addition, estimate the percentage of bare ground and litter.

2. Superimpose a line intercept plot approximately within the geometric center of the sampling area. We assume that you will be using a 50 to 100 m metal or reinforced fiberglass tape.

a. Begin by deciding on the length and configuration of the transect. In a chaparral or forested area the line should be 50 m or more; in an herbaceous community, 30-50 m. In a small area within a forest, a 90 degree bend in the line as described above is permissible.

b. Anchor one end of the tape using a slender metal tent stake or chaining pin and carefully stretch the tape out in a randomly chosen direction maintaining as straight a line as possible by "threading" the tape around or through objects. If a very large boulder or tree is encountered which prevents a straight line from being established, choose another direction. If a right angle bend is desired run the tape through a chaining pin at the center point and make your turn. Anchor the opposite end of the tape.

3. Subdivide the vegetation to be measured into functional layers coinciding with those on the CPVAC Vegetation Record sheet (trees, shrubs [including cacti, agavaceous plants, etc.], forbs, graminoids, herbs, microphytic crust, litter and bare ground; layers below shrubs can be amalgamated into one layer for the purposes of recording (see accompanying data sheet). Assume that all plant crowns give 100% cover, i.e., without holes and that crown outlines are regular and entire as viewed above (these assumptions are not true, of course, but they will simplify the work).

a. Forbs, Graminoids, Herbs, Mosses, Litter and Bare Ground. Begin at the zero end of the tape and record the length of the line intercepted by each individual plant portion encountered, according to species, as you progress toward the end of the line (Appendix II, Fig. 3). "Litter" and "bare ground" can be recorded as if they were a "species." However, please note that bare ground is that portion of the transect which sunlight (at high noon) would shine upon — it does not include bare ground under the canopy of trees and shrubs. Litter, however, is all organic, detrital material under the cover of trees and shrubs and that is exposed to sunlight. Unless there is some specific reason not to, microphytic crusts, mosses, lichens, etc., can also be lumped into one category. For convenience in measuring and in order to insure the inclusion of smaller species, it is desirable to consider all the vegetation intercepted by a strip, one cm wide, one side of the line (Phillips 1959, Brower et al. 1990). The easiest way to do this is to either measure the plants' intercepts directly with a rule or meter stick or read the length directly off the tape. Sighting down along the edge of the line, being careful to maintain a vertical (90° to tape) projection of the plant cover, observe the length of the tape at the beginning of the intercept and the length at the end of the intercept. Make your measurements accurate to one centimeter. Mentally subtract the difference (use a scratch-pad if needed); this is the intercept; record it on the data sheet. Do this for all individuals according to species along the entire length of the tape. Annual grasses can be given a cover value of 0.1 cm. Remember that in particularly dense cover, intercepts for different individual plants may overlap. Therefore, it is entirely possible to come up with a total cover exceeding 100%, especially when all three layers are added together.

b. Shrub and Tall Dicotyledonous Herb Layer. Species cover within the shrub layer is accomplished in the same manner as in the previous layer. However, because a large shrub may have an intercept well over one meter, direct reading with a meter stick may be inconvenient. Reading the intercept directly off the tape is the method of choice.

c. Tree Layer. This is the most difficult layer to measure because in most cases it involves assessing the intercept of an overhead canopy. In order to do this accurately, a sighting device is often employed. The device may be as simple as a 20 cm long tube (cardboard mailing tube, pvc pipe [or equivalent], one end of which has been fitted with crosshairs of thread or monofilament, the other end fitted with a peep-hole and mirror set at a 45° angle and a plumb bob), or it may be a commercially obtainable two-way right angle prism with an attached plumb bob. In any case, the intercept is obtained in much the same way as above except that the line is straddled while the sighting device is employed to ascertain the beginning and ending of the tree canopy's intercepts. The plumb bob indicates the length along the tape. Ideally, a second person should be employed to facilitate recording.

| Date: | Observers: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Habitat and Layer (Stratum): | | | | | | | | | | |
| Location: | | | | | | | | | | |
| Transect (or interval) Identification: | | | | | | | | | | |
| Length of Transect: | | | | | | | | | | |
| Plant No. | Species | Species | Species | Species | Species | Species | Species | Species | Species | Species |
| | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length | Interval Length |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
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| 17 | | | | | | | | | | |
| 18 | | | | | | | | | | |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| **Total** | | | | | | | | | | |
| **% Cover** | | | | | | | | | | |
| **Rel.% Cover** | | | | | | | | | | |
| **Rank** | | | | | | | | | | |

*Figure 3. Line Intercept Data Collection Sheet.*

4. Summarize the data according to layers and plant species. Add up the intercepts and derive the percent cover of each species according to the formulae given above. Cover values can be amalgamated according to layers or species and compared with the initial estimates which you wrote down on the Vegetation Record Sheet. It is also hoped that the species cover estimates obtained through the line intercept will correspond strongly with the presence values assigned to species on the Vegetation Record Sheet. If they do not, adjustments are in order.

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# APPENDIX III

## Preparing Herbarium Specimens of Vascular Plants

C. Earle Smith

# PREPARING HERBARIUM SPECIMENS OF VASCULAR PLANTS

Agriculture Information Bulletin No. 348

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

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# CONTENTS



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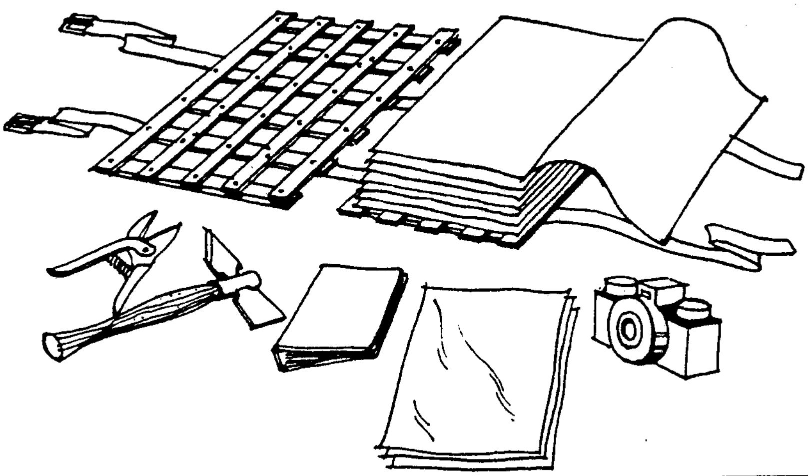
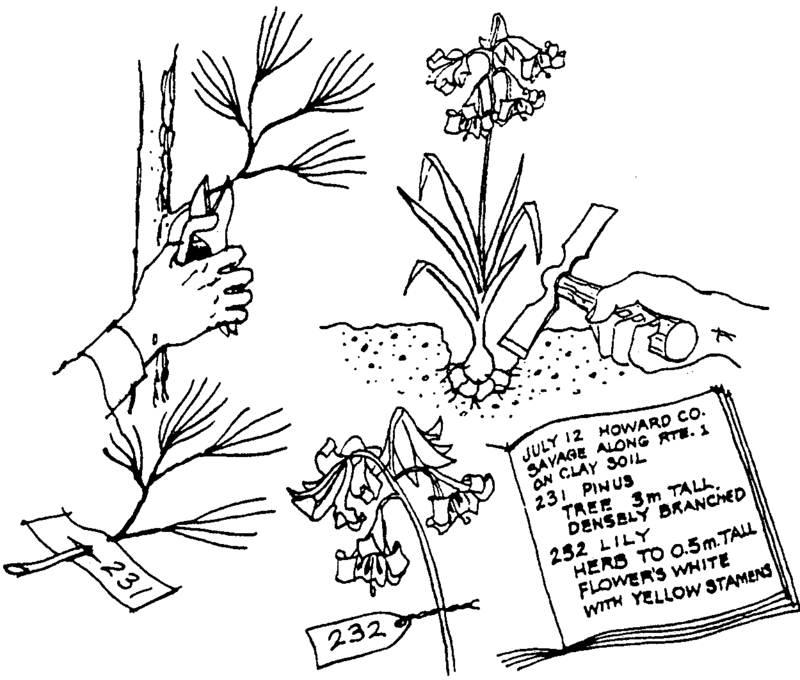
# Short Guide to Preparing an Herbarium Specimen



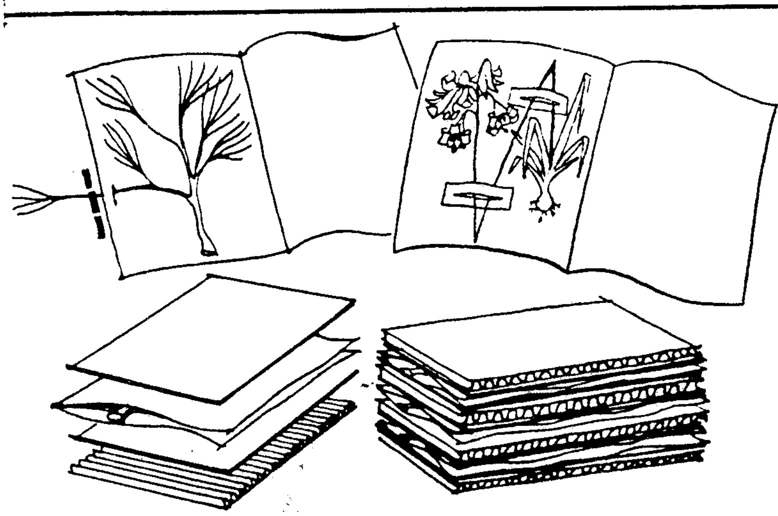
A. Assemble the equipment.

1. Prepare the press with folds of newspapers to receive the specimens.
2. Gather tools and supplies: cutting tools, digging tool, notebook, plastic bags to hold unpressed specimens, and a camera to record difficult-to-describe plant parts.



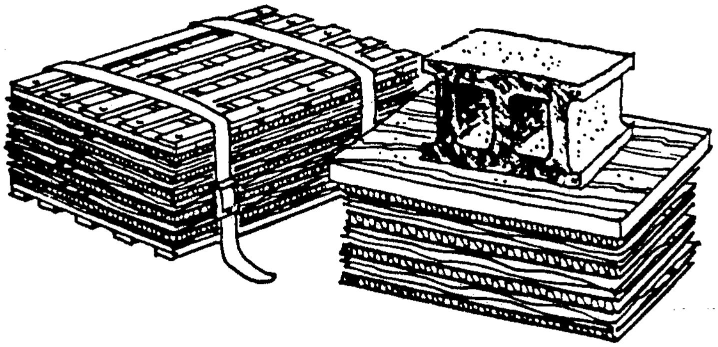

B. Collect the specimen and record the data.

1. Survey the plants to be collected to find the most representative specimens.
2. Cut or dig the selected plant parts.
3. Make detailed notes of observations that may be forgotten.
4. Place the specimens in a container for transport or in the press. If notes are made and separate parts collected, give the same identifying number to portions so they can be associated later.



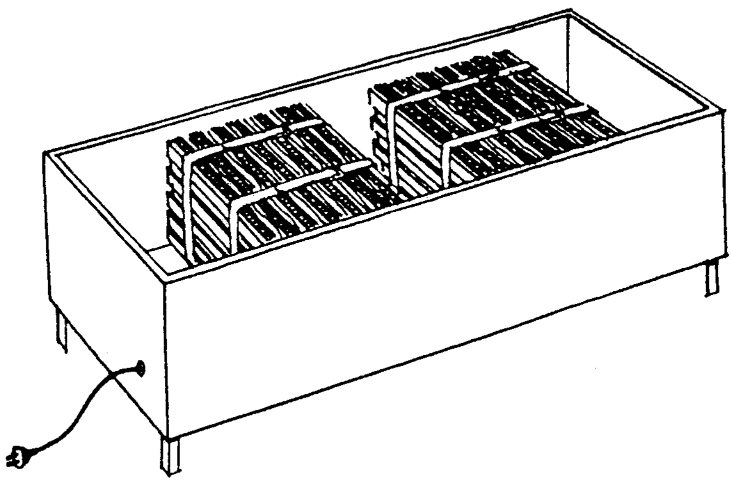
C. Prepare the specimen for pressing.

1. Place specimen in numbered newspaper fold.
2. Cut away excess parts, arrange leaves and flowers.
3. Write notes beside number in notebook; describe area, habit of plant, colors that may change, odors, and any special details.
4. Place fold between driers (adsorbent blotting paper) and corrugates (corrugated cardboard with channels running the width of the 12- by 17-inch piece) or heavy pads of newspaper.



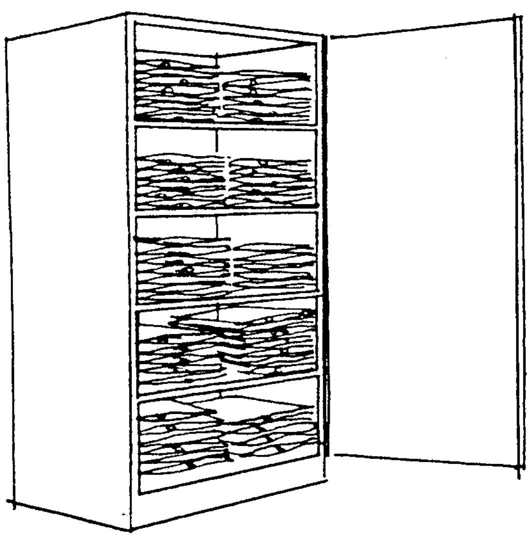
D. Press the specimen.

1. Press the specimen with its driers and corrugates tightly between press frames or weight heavily beneath board or books.



E. Dry the specimen.

1. Change driers or newspaper pads in 24 hours and thereafter as they become moist. Do not disturb the specimens in the newspaper folds.
2. When dry to the touch, test for incompletely dried specimens (incompletely dried specimens will feel cooler and ends will droop when lifted from the fold).



F. Store the specimen.

1. Store dried specimens in thei folds tied between corrugate or mount on stiff 12- by 16-inch paper with bookbinder's Hol land tape strips, casein, o plastic glue.
2. Label all specimens before stor age or mounting.
3. Store only in insect-resistan furniture.

Additional, detailed information o preparing herbarium specimens can b found in the rest of this bulletin.

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# PREPARING HERBARIUM SPECIMENS OF VASCULAR PLANTS

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## THE HERBARIUM SPECIMEN AND ITS PREPARATION

The correct methods of preparing plant specimens for the herbarium are as many and varied as the correct methods of baking a cake. Every practicioner finds a convenient method that he will defend against all intruders. The truly correct method of preparing herbarium specimens is that which produces the most representative dried sample in the shortest possible time.

### The Herbarium Specimen

The most important element in botanical collecting is the permanent record produced, which is a specimen or a suite of specimens representing a living plant (fig. 1). For mos purposes, an identifiable specimen can be de fined as one with either flowers or fruits, or both because most botanical literature discusses th differences in kinds of plants in terms o reproductive structures. This is generally tru for all groups of plants including the seaweeds mushrooms, mosses, and ferns, as well as th seed-bearing plants. Speciments of ferns an seed-bearing plants tend to be more bulky an difficult to prepare so this bulletin will be con cerned with these plants. These, in fact, are th "vascular plants" of the title, because the include in their structures a system of tube for transport of liquid (the vascular system).

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Figure 1.—Suite of specimens representing *Gunnera peltata* Phil.

Plant specimens are kept in an herbarium (collection of herbs, literally, although the term is now used for any kind of dried plant collection). To facilitate the storage of specimens and to allow the greatest flexibility in exchanging or borrowing specimens, the herbaria of the United States mount dried, pressed plants on sheets of stiff paper measuring about 11½ by 16½ inches (28.7 by 41.7 cm.). Because there are a number of facts about a plant (height of tree, geographical place where the plant was growing, kind of area where the plant was found, colors, and odors) that do not show in the dried specimen, additional information is placed on a label that is fastened to the lower right corner of the sheet of mounting paper. Many plant specimens do not hold together well and some have only a few flowers, so the botanist dissecting the flowers wishes to preserve the dissected parts. He places all loose parts in folded packets glued to the mounting sheet. Sometimes the appearance of a plant defies description and the collector saves much time by photographing the plant before specimens are taken. Such photographs are usually fastened to the mounting sheet also.

Herbarium specimens are identified as accurately as possible and are then filed in standard-size manila folders with closely related species. These in turn are aggregated into groups of closely related genera and into families. Most frequently, several manila folders are stored in a pigeonhole in the herbarium case according to the Engler and Prantl scheme of classification (*16*) [1] so that an individual genus or species may be quickly recovered. (The Engler and Prantl classification attempts to group all plants in their natural relationship to one another. This is the most widespread of several systems of classification.) The earlier herbarium specimens become the standards against which later specimens are compared, and, thus, the accuracy of the identifications is critical. The more complete the specimen and the more detailed the notes on the label, the more accurate the identification can be.

Herbarium specimens are very important records. Perhaps the most important function of an herbarium specimen is to record the complexity that is a plant species. Botanists have long known that words or illustrations cannot replace an actual sample of a plant as a standard for comparison. This is recognized in the codification of rules for plant nomenclature where a type specimen is required as the base for a plant name. The first collection that is described as a new species becomes the type specimen against which all future identifications of this species must be measured. Any scientist doing research involving living plants should prepare an herbarium specimen for permanent record in case further work based on the same material is necessary or the original identification of the plant is questioned. Whenever samples of plants are submitted for any sort of analysis, a specimen of the plant from which the sample was prepared ought to be held as a record. Ever the amateur gardener may find that dried, pressed specimens of some of his plants may serve as valuable standards of size and identity for new cultivars tried in subsequent growing seasons. Anyone involved in the breeding of plants should preserve representative specimens as a check for the improvement or regression of characters in progeny in the breeding program. A few minutes spent in carefully preparing an herbarium specimen can save much time if the exact identity of a particular plant must eventually be known or recalled.

[1] Italic numbers in parentheses refer to Selected References, page 26.

## Preparing an Effective Herbarium Specimen

An effective herbarium specimen not only is identifiable and serves as a record of the species, but also shows the range of variation of the species in the place where the specimen originated. Although the standardization of the size of mounting paper in the herbaria of the United States has resulted in the universal exchageability and storability of specimens, it has tended, at the same time, to bias the collector in favor of a specimen that will look neat when fastened to the herbarium sheet. In spite of the fact that it must eventually fit a standard-size herbarium sheet, a sample should be selected first for its value as a representative of foliar size and variation, inflorescence size and variation, and stem aspect of the population of the species. The specimen should be selected next for its complete normalcy unless that specimen is to show the damaging effects of fungal or insect attack. Finally, the specimen should be attractive once it is mounted if it is possible to prepare a pretty as well as a representative specimen. Many times it will be impossible to find representative specimens that are also attractive after they are pressed (fig. 2).

### *Collecting the Specimen*

For most people, collecting the specimen is the most enjoyable part of preparing herbarium specimens. Because there is an element of fun and pleasure involved, there is sometimes a lack of understanding of importance of collecting representative and complete examples to go into the press. Often considerable search must be made before a suitable portion of a plant will be found.

TOOLS AND EQUIPMENT NEEDED.—Tools frequently are a matter of personal preference. A New Englander finds an ax easy to use, but a Mexican generally prefers a machete. A few tools are useful enough to be recommended for everyone who wishes to collect plants.

Field pressing equipment is needed to prepare adequate botanical specimens. A field press may be made of any type of material that can be used as end boards to exert uniform pressure over a 12- by 16-inch area. Many botanists carry a press with fiber or plywood ends, but the standard lattice press frame made of crossed strips of a tough wood like ash, hickory, or oak is very satisfactory (fig. 3). As a collecting press, the frames may be held together with sash cord or web straps, or a special system may be installed in which the fastening on one side of the frame acts as a set of hinges so the press will open from one side only.

In the past, botanists often carried a tin box known as a vasculum into which plant materials were placed pending an opportunity to press them. With the multiplicity of plastic bags now available, most botanists use these for field carrying because they take up little space before they are filled and are easily disposed of after use. When using a general repository for a number of specimens before pressing them, it is well to remember that they must be bundled and labeled to prevent mixing if there are several collections of the same species. Also, flowers and other structures tend to become dislodged, so extra material should be gathered to ensure enough to make up the required duplicates when the plants are pressed.

A short-handle field pick is one of the most useful tools that can be found for collecting herbaceous material. Often, the soil is so compact or full of rock that garden trowels and similar implements are ineffective. Unfortunately, the demand for special botanical field picks with a narrow, hatchetlike blade on one side and a small mattocklike blade on the other side is so small that they are very difficult to locate. Army entrenching tools and similar make-do aids can serve a very useful purpose in collecting. If collecting is to be done over any distance, though, the lighter the digging tool, the better, because the load of plant specimens will grow heavy and can become rather bulky.

Cutting tools are indispensable for efficient collection and preparation of specimens. A pocketknife will serve for many uses but it will not work effectively on twigs greater than about three-eighths inch in diameter if the wood of the plant is very dense. A garden pruning tool of the knife-on-anvil type of heavy forged construction will cut through most wood up to about 1 inch in diameter. For heavy cutting jobs such as tree felling, an ax is the tool usually employed although a sharp machete is nearly as effective if the user is skilled. A machete is not recommended for amateurs because on a downstroke the heavy blade can cut nearly through a leg.

Unless a collector is skilled at sketching, a camera is a necessary part of the collecting apparatus. Many details about the appearance of plants in the field are both difficult to express and require more extensive field notes than most people wish to write. The camera will capture the shape and manner of branching of a tree much more surely than a note. If a plant is bulky and must be divided into portions before pressing, a photograph of the intact part taken with a scale will provide a descrip-

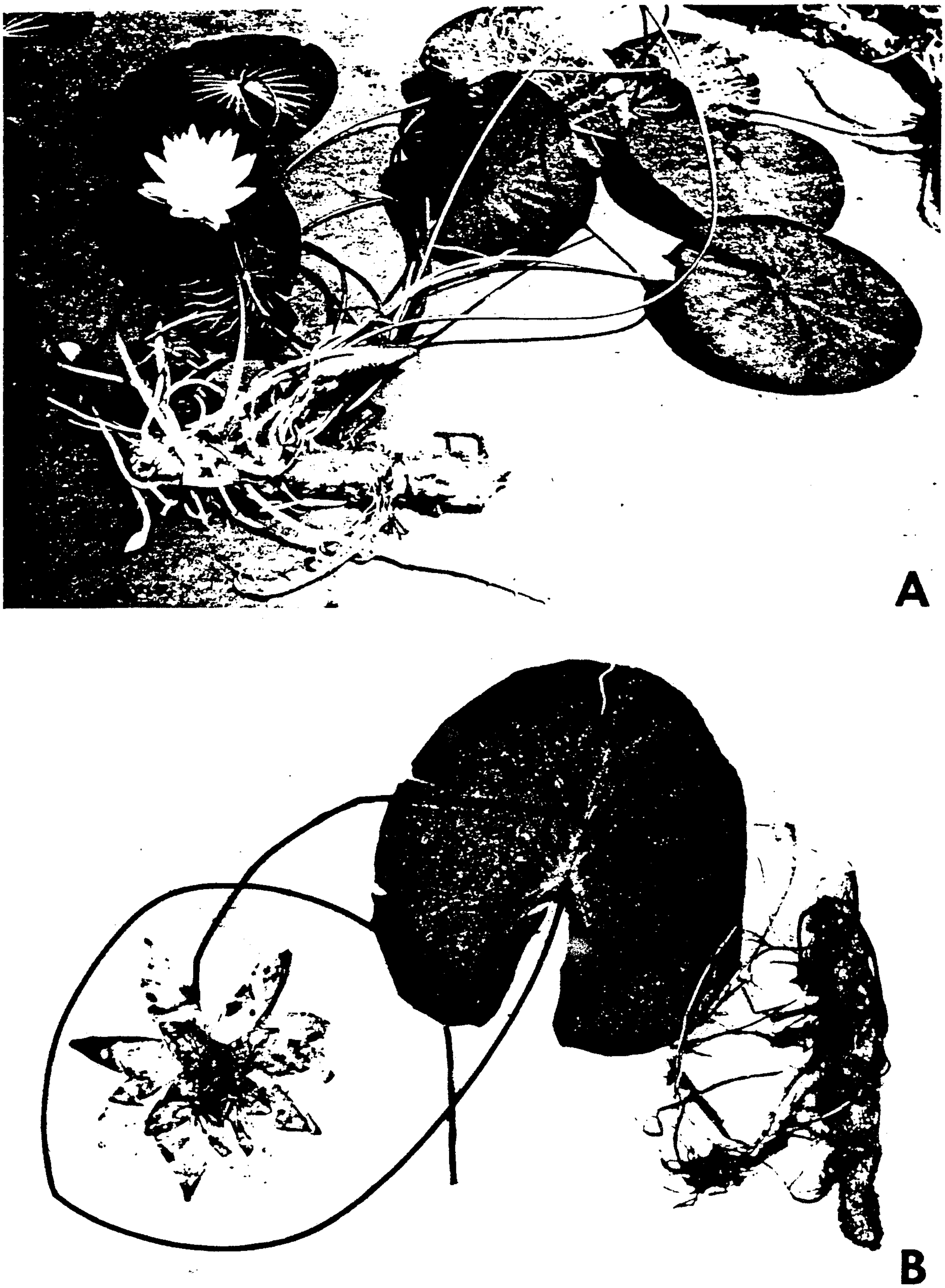


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FIGURE 2.—*A*, Plant of *Nymphaea odorata* Ait. as it was collected; *B*, dried, pressed specimen of the same plant in newsprint fold with a field label.

tion of shape and size with no further effort on the part of the collector. Unfortunately, color films are not yet permanent enough to be relied on for color recording, so it is still advisable to note the colors of plant parts before placing the specimen in the press.

PROCEDURES AND SUGGESTIONS.—When collecting specimens in a new area, make a short survey of the amount of material that may be available, the kinds of terrain that will have to be crossed, the condition of the available plants, and an evaluation of the amount of time the job is likely to consume. In this way, the more important specimens can be collected first, and the less important plants can be left for another time if the collector must allow sufficient time for preparing difficult-to-press specimens and recording additional notes for special material.

After making the initial survey, collect the more delicate specimens first so that they may be packed away safely and will not be destroyed by tougher plants laid on top. If time runs out and light fades, the more harsh plant materials can be packed away in a bundle and will still be in good condition the next morning.

Directions for collecting an individual specimen are difficult to give. Perhaps the best advice is to know something about the taxonomy of the group to which the plant belongs and then use your imagination in selecting material for representative and complete specimens. Hard-and-fast rules for making a perfect specimen can lead to somewhat less than representative specimens. Although it is admirable if the specimen is beautiful as well as representative, it is much more important that it is representative. The specimen should show the range of variation of the parts of the individual plant. It should also show the range of variation of the population of the species. Thus, more than one herbarium sheet may be required.

Ordinarily, small herbaceous plants must be

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FIGURE 3.—Lattice-type press frames and web trunk straps with quick-release buckles.

collected in quantity so that each herbarium sheet will consist of several plants. Some small plants fit neatly one to a sheet with one or two bends in the stem. All small plants should have the root system included with the specimen, and a note should be made as to whether the plant is an annual, biennial, or perennial.

Some herbaceous plants are much larger than the press sheet will accommodate, and an appropriate portion of the plant must be chosen to place in the press. Select a plant with intermediate-size foliage and inflorescence; include on the sheet a separate leaf of the largest size found on the plant. If the leaves along the stem are crowded and overlapping will obscure details of size, shape, and other features, remove a number of the leaves, but do not remove petioles or bases that indicate points of attachment. A large, complex inflorescence must be similarly thinned. Many of these thinnings can be pressed separately and packed as extra flowers and fruit so that parts of the whole specimen will not have to be removed for dissection.

Woody plants are usually too large to press whole. As with large herbaceous plants, a representative portion of the plant must be selected for the press. Always look over the shrub or tree carefully if it is large or in dense growth. Many plants produce radically different foliage on the outside of the plant where light is plentiful and inside or underneath where the leaves are constantly shaded. Also, foliage on shoots produced after a tree or shrub has been severely damaged or on shoots arising from the trunk is often much different from the foliage usually found on the same plant. In some plants, the foliage on flowering branches is different from that on sterile branches. Specimens should also show the older branchlets with the manner of branching typical of the species. When a specimen of a deciduous woody plant is to be as complete as possible, it is obviously impossible to collect flowering, fruiting, and winter specimens at the same time. At the time of the first collection, the plant should be marked with a permanent tag securely fastened so that curious birds and children will not be able to remove it. Subsequent collections can be made from the same plant. Often it is helpful to remove a small piece of bark to be included with tree specimens.

A few special problems are sure to come up sooner or later. One of these is pressing large underground parts of herbaceous plants. These can be treated in the manner described for fleshy stems and inflorescences. (See p. 19.) Sections are cut to show the length and the thickness of the part. Whenever possible, include material to show the outside surface, particularly of bulbs, because this surface is often important in determining the identity of the plant. Some plants will have a heavily tufted fibrous root system. Because this root system will be too bulky in the press, trim it to thin it down. If at all possible, always include enough rhizome to show the sequence of growth and branching. Grasses and sedges that grow as clumps must be divided before pressing. When this is necessary, the label should indicate that only a part of clump was pressed.

A few plants will have leaves so large that a single leaf will not fit on a standard press sheet. Palms usually are difficult to handle because of this. The leaf may be divided just to one side of the midrib and about one-half of the leaf with the petiole can be pressed (fig. 4). If a half leaf is still too large, the dimensions of the whole leaf should be noted (the leaf can be photographed with a scale) and representative portions, including the tip, the base, and the middle of the leaf, can be pressed (fig. 5).

In general, a little care will result in very satisfactory herbarium specimens. Whenever bulky stems interfere with the pressure distribution in the press, a few extra pads to fill out the space will result in much better and smoother samples. If at all possible, arrange leaves or fold a leaf so that both the top and the underside of the leaves may be seen. A similar arrangement for large flowers is necessary. Because the petals will hide the details of the calyx in some species such as the mallows (*Hibiscus* spp.), one flower per specimen should be turned to show the underside and the calyx.

### *Recording the Data*

One of the most important aspects of preparing an effective herbarium specimen is recording accompanying data. Although the collector

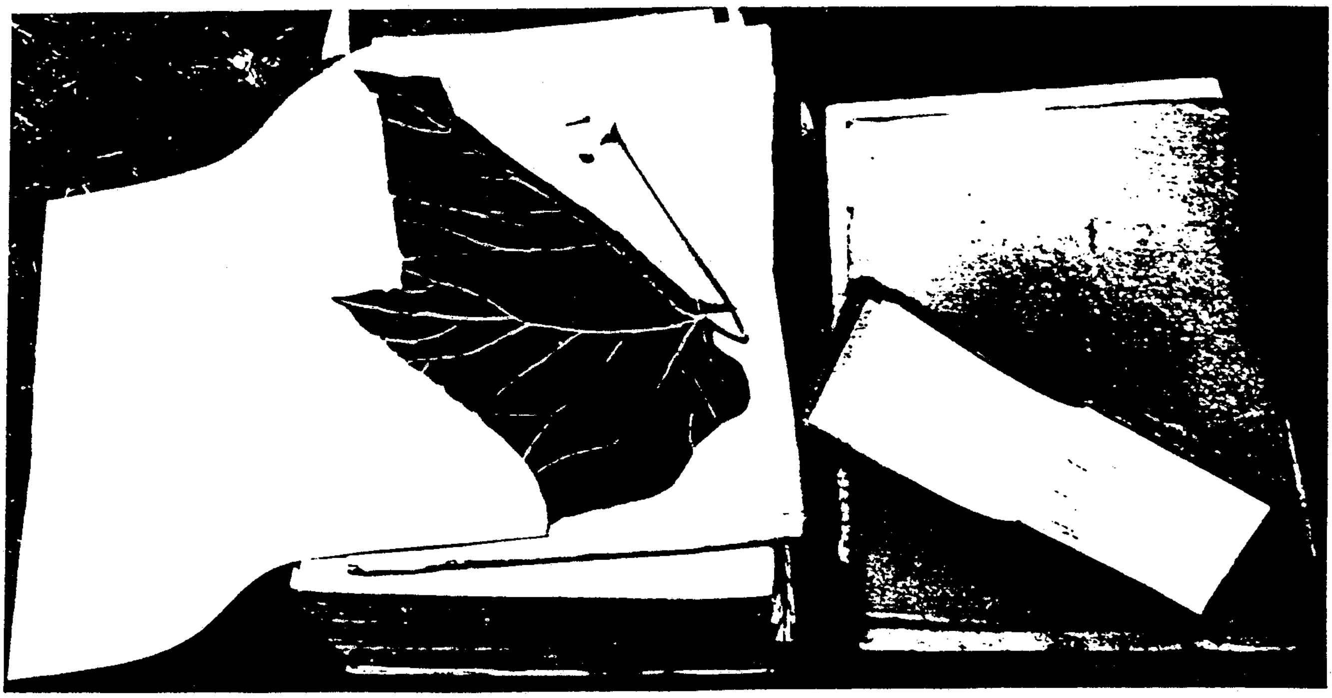

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FIGURE 4.—Large leaf cut to one side of the median line to fit newsprint fold. Note the stub of the petiole of an opposing leaf to show leaf position on the stem.

always hopes that the vivid colors of a beautiful flower will be captured, this is rarely the case. Almost all flower colors undergo some change in the process of drying. Similarly, odors vanish for the most part, although the members of the mint family and a few others may retain some odor. Sizes and shapes of plants often cannot be seen in the prepared specimen. These facts and many other details are needed or helpful in making a correct identification.

Correct ways of recording data about plants are many. One of the most important facets of the data-recording process, though, is to record the data on the spot, or as soon afterward as possible. Although a few hours do not seem to be much time, the kaleidoscopic impressions from a full day's field work are very difficult to sort late in the evening. Each time it is necessary to place specimens in a field press, all notes should be made on the plants going into the press. If collecting is being done by placing material in a vasculum or collecting bag, a slit tag (fig. 6) with data should go on the stem of each collection because this material will probably not be placed in the press until the end of the day.

After the plant specimens are prepared for drying, the permanent recording of field data can begin. All the temporary notes made during the collecting are now transferred to a record book or card, preferably of good-quality paper. The inscription is made with a smear-free, waterproof ink or pencil. For ease in relating data in the record book to the dried specimens, a serial number system is used and the same number is placed on both the covering press sheet and the margin of the book. A number of collectors have elaborate schemes whereby the number indicates the collection date, locality, or other information, but this serves little purpose unless the numbers are to be used in a special statistical study. A few collectors have initiated a new number series for each collecting trip or for each year. This is not a good practice because the repeating numbers may be easily confused if the specimens are permanently deposited in a working collection and monographers cite the label data. More complex number systems are more frequently misquoted.

What should the record include? One of the most satisfactory answers to this is received from an herbarium label (fig. 7). At the top

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FIGURE 5.—Specimen leaf of *Juanea australis* Drude prepared in sections.

of the label the country or other major political area is noted most often; for example, "Plants of Zambia." Although the name of the institution sponsoring the collection may appear at the top, this is generally better recorded at the bottom of the label since that name is not essential to an understanding of the biology of the plant. Beneath the top line at the upper left, the collector's number is sometimes inserted or it may be inserted immediately after the collector's name near the bottom of the label. The scientific name of the plant appears at the top of the label, after the country or area is noted. At this point on the label, it is convenient to leave sufficient room to include notes about plant size, flower color, fruit shape and size, and any other information about the individual specimen. These notes must be placed on the label by hand or typewriter. Below this the geographical information in gradually decreasing magnitude of area is detailed; for example "Maryland, Howard County, south of Baltimore, along U.S. Route 1, near Savage." Any information concerning the habitat, soil, and moisture conditions can be noted next. The bottom line on the label is usually the name of the collector and the date on which the collection was made.

Obviously, considerable amounts of information can be accumulated about an individual specimen. The problem of recording all of this in the field book is simplified by using the geographical information and the date as the heading for a block of numbers representing specimens collected in the area. Under each number, only information about the individual plant is recorded. With this system, it is possible to accommodate all the information to be recorded into a standardized spacing so that the collector's numbers at left-hand margin of the page can be stamped with a consecutive numbering machine before going into the field. An asterisk beside the first number at a new locality indicates that the geographical information and data will be found at the top of the page.

The order of information on the label has become fairly standardized because professional botanists usually collect 5 to 10 duplicate specimens of interesting plants for distribution to a number of herbaria. The problem of placing all the information on the label is then simplified by having printed labels made for blocks of numbers and the typist has only to fill in the collector's number and the notes about the individual plant. If the number is placed at the upper left just over the space for the scientific name, all the typing can be done with one positioning of the label; if the number must be placed after the collector's name, the label must frequently be repositioned in the machine. All permanent labels for plant specimens should be typed or clearly printed so that there is no chance for error or confusion later.

*Pressing the Specimen*

Actual pressing of the herbarium specimen involves two problems: (1) Pressure sufficient to prevent curling of leaves and other plant parts during drying; and (2) removal of the moisture in the plant tissue as rapidly as possible without changing the appearance of the specimen. The first problem is solved easily by providing surfaces on either side of the plant specimen to hold all the organs in place. Almost all professionally prepared specimens are pressed in a sandwich involving a folded newspaper page to hold the specimens between two sheets of adsorbent (blotting) paper that are in turn flanked by two pieces of corrugated cardboard (corrugates) in which the channels run the width of the board. If all the elements of the sandwich are cut to a standard size of about 12 by 16 inches, there will be no difficult fitting specimens to the size dictated by the mounting paper. In an emergency or for only a few specimens, thick pads of newsprint can be substituted for blotting paper and corrugates.

Because corrugated cardboard eventually collapses, some collectors prefer to use sheets of corrugated aluminum. These are commercially available through biological supply houses.

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FIGURE 6.—Slit tag on stem of collected plant, containing data to distinguish plant from other collections of the same or similar plants.

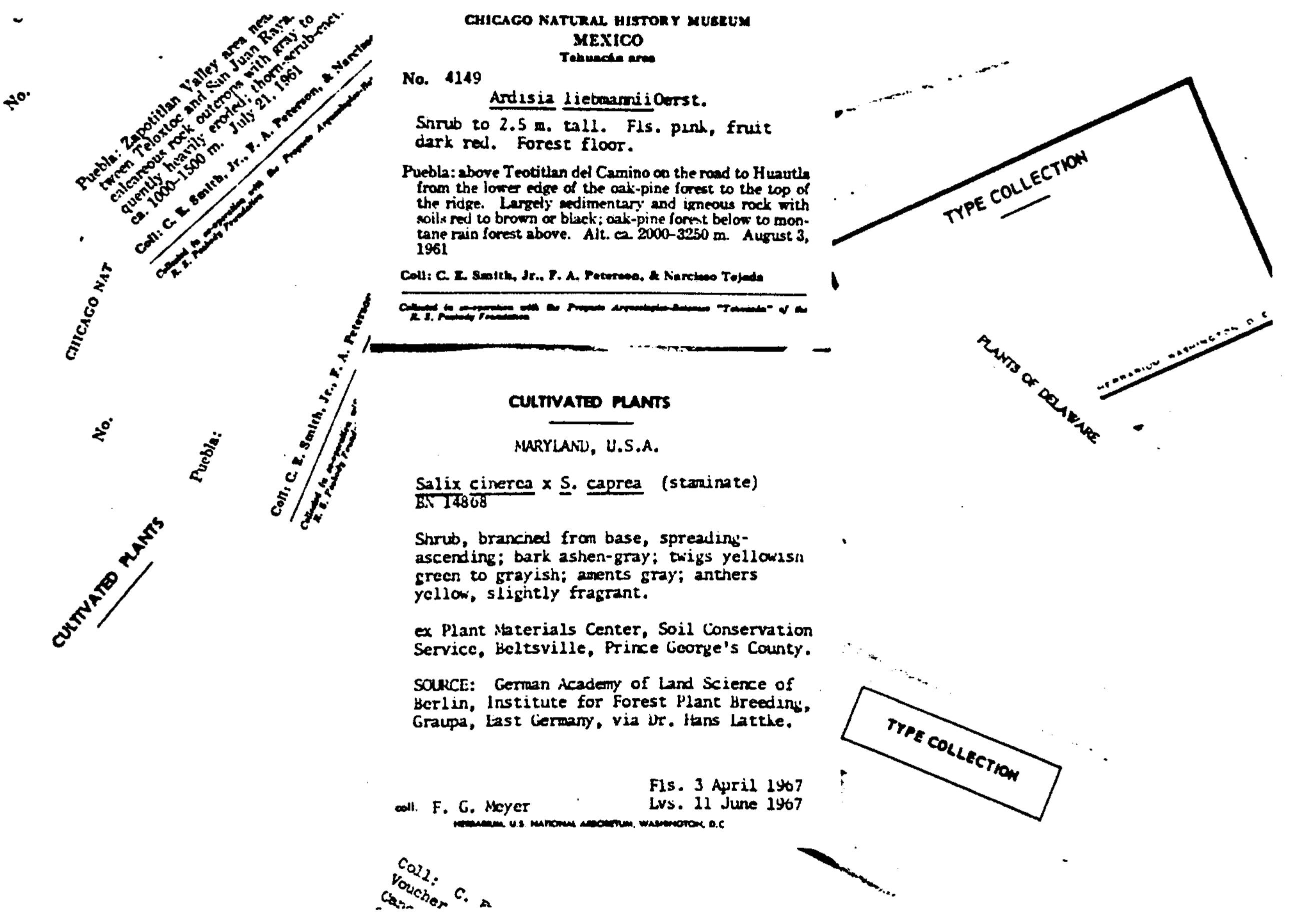


FIGURE 7.—Examples of labels, with basic information printed and notes about the individual collection typed.

Even though these aluminum corrugates stand up well under hard usage, it should be borne in mind that they weigh more than cardboard corrugates, the edges can inflict annoying cuts until they have been used long enough to become rounded, and they are too expensive to be abandoned after use in the field. Furthermore, they cannot be used to reinforce bundles of dried specimens as can cardboard corrugates.

Pressure is applied to the specimens to be pressed by any available and practical means. Large screw-type book presses and pieces of wide lumber weighted down with stones or bricks have both been used. For repeated use, the more easily handled press frames made of crossed ash or oak strips riveted at the crossings with large copper rivets provide uniform pressure when held by two web trunk straps or ropes tied with slip knots (fig. 3, p. 5). Usually straps with quick-release buckles are cut to the length needed to encompass the largest stack of specimens that might be placed in the press. Placing more than 60 to 90 specimens in a press, depending upon the bulk and shape of the plant material, often results in poor-quality specimens unless extra care is taken to distribute pressure evenly.

Plant press frames are readily available from biological supply houses or they can be easily made of slats of well-seasoned ash, hickory, oak, or other tough, flexible wood. Strips 1/4 inch (6 mm.) thick ripped from the edge of a dressed board 1 inch (2.2 cm.) thick with a straight grain are ideal. Use five pieces 16 inches (40.5 cm.) long and six pieces 12 inches (30 cm.) long to form a lattice. All the longer pieces should be placed on the same side of the lattice. The ends of each piece are drilled and fastened into place with a copper rivet. Within the lattice, the crossings of the slats may be nailed with brads. The accompanying plan illustrates the construction of a usable press frame (fig. 8, *B*). (See also fig. 3, p. 5.)

### *Drying the Specimen*

Ordinarily, each specimen is laid into a fold of newsprint in the field press or at intervals as the collecting bag or vasculum is emptied. After they have been collected, specimens should not be left unpressed any longer than necessary. Although enough material for 2 or even 3 specimens may be crammed into a single fold under emergency conditions, this is not recommended as a general practice. Leaves and inflorescences tend to become entangled and stems make pressure marks on leaves and petals.

To set up a drying press, each specimen-bearing fold is enclosed between two driers (adsorbent paper) and adjacent driers are separated by corrugates. The press sequence, starting from one end, is as follows: corrugate, drier, fold with specimen, drier, corrugate, drier, fold with specimen, and so forth. Some botanists use only one drier per fold, but two driers per fold tend to mold better around stems of woody specimens and produce smoother leaves and flowers. Whenever specimens with particularly bulky stems, fruits, or flowers are put in the drying press, additional packing of folded driers, newsprint, or specially cut corrugates must be inserted both to apply proper pressure on thinner plant parts and to allow the press to stack evenly. Uneven stacks always tend to squirt out on the bulky side when pressure is applied and few things are more conducive to frayed nerves than an unruly press after a hard field day.

If this problem is frequently encountered, it

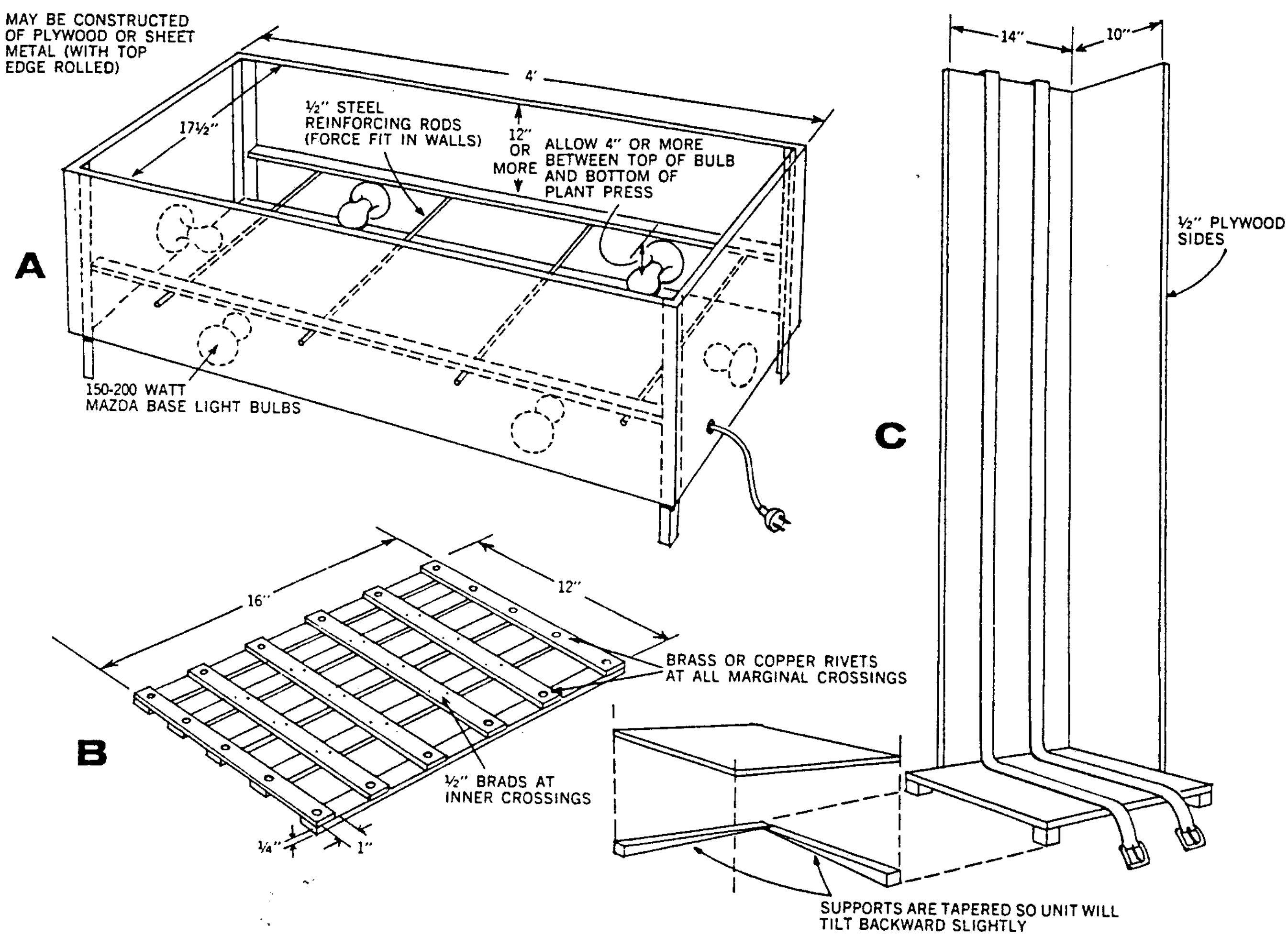


FIGURE 8.—Designs for: *A*, Heated drying rack; *B*, lattice-type plant press frame; *C*, stacking corner.

will be well to use specially cut blocks of urethane foam to fill out the press. This material is now frequently used for upholstering and is available in furniture repair shops. With a razor blade or other very sharp instrument, blocks and strips of an appropriate size and shape can be cut to fill in around a bulky plant part. If the foam fill block is cut two or three times as thick as the bulky plant part, pressure in the press will mold it into place so that thin leaves and flowers will be flat. The foam fill block is apparently sufficiently porous to allow moisture to escape. However, be cautious in the use of any padding material. Too much padding will result in the accumulation of moisture in the padding with a resultant delay in drying of the specimens, which may lead to mold formation or other undesirable results.

After the stack for the press has been assembled (i.e., corrugate, drier, specimen, drier, corrugate, etc., which are assembled horizontally), the press frames are put on the ends. The stack is held together and pressure is applied by two straps or ropes. It is usually most practical to have the buckles or knots along the axis of the press. If these are placed strategically near the far end of a large press stack, then the proper pressure can be achieved by laying the press on the floor, placing the feet on the press frame most distant from the buckles and pulling both straps evenly toward the feet. The side on which the buckles or knots are located will pull up faster than the other side. The press will have to be stood on one end and the press frame on top pressed down on the high side so the strap or rope slips around and the press frames are parallel. This may have to be repeated as pressure is applied.

Theories concerning the amount of pressure to be applied to drying specimens are many. Some botanists apply only light pressure immediately and tighten the press gradually as the specimens dry. However, pressure becomes less as the specimens lose water and the tissue becomes thinner. With woody plant material particularly, I find that the more pressure applied initially, the better, because the driers and corrugates then mold around the thicker parts and leaves are more wrinkle free. Two bad effects from too much pressure are: (1) The corrugates may be so completely collapsed that the air passages are blocked (their job being primarily to carry moisture out of the press): and (2) fleshy plant parts may be crushed and smeared into an unrecognizable mass. I have never been strong enough to achieve the former with fresh strong corrugates although reused corrugates collapse eventually. On one or two occasions, I have mashed a portion of a specimen. This clearly proves that the specimen should have been sketched or photographed and sectioned in the first place.

The straps or ropes will usually have to be tightened once or twice during the initial stages of drying. As plant material loses moisture, it shrinks. If the pressure on the press is not adjusted about every 8 hours, the leaves and flowers may wrinkle.

When aluminum corrugates are used, too much pressure can result in parallel pressure marks across the specimens. The more coarse the corrugation in the aluminum, the more likely this is to happen. Although this problem may be solved readily by less pressure, it frequently can also be solved by adding an additional drier on each side of the specimen fold.

If no source of artificial heat is available, the completed press should be placed in the sun during the day and under cover at night. If the press is so oriented that the prevailing breeze blows through the channels of the corrugates, drying will be more rapid. If the collector is operating a field vehicle, the press may be tied on top so that the air movement caused by the movement of the vehicle will flow through the corrugates. In open country with low humidity, specimens will dry very rapidly on a moving vehicle.

At the end of 24 hours, the press should be opened and the driers and corrugates completely changed so that each newsprint fold is surrounded by dry material. Although it is possible to open folds with specimens with harsh foliage at this point, do not attempt to look at delicate specimens. In their semidry condition, they will partly stick to the newsprint and collapse into a mass as they pull free. The material should have been arranged when the specimens were originally placed in the drying press. All of the moist driers and corrugates must be thoroughly dried before reuse. These are generally spread in the sun. If the schedule for changing the press can be so arranged that driers and corrugates hot from the sun can be used, then drying of the specimens will be hastened.

Whenever possible, use artificial heat to dry specimens. In some areas of high atmospheric humidity, it is impossible to dry specimens without artificial heat. In other areas, artificial heat may not be mandatory, but it will be a definite help in drying specimens of fleshy plants.

Any source of heat is usable, as long as it can be channeled through the corrugates of the press. However, open campfires are far from desirable because a whole press full of specimens may be lost through fire in the later stage of drying. There is, of course, the added disadvantage of soot from an open flame.

In remote areas, kerosene and gasoline stoves and lanterns have been effectively used to dry specimens. Generally, the press is suspended above the heat source, high enough to prevent its catching fire. A metal baffle between the flame and the press will guard against a hot spot and distribute the heat more effectively. A cloth skirt tied around the press and nearly touching the ground improves the efficiency of the drying.

Wherever electricity is available, an efficient drier can be assembled by using light bulbs as a heat source. 100-watt or larger bulbs are best, and there is usually little danger of getting too large a bulb because very large wattage bulbs rarely fit into a Mazda socket. The press is suspended about 6 inches above the light bulbs. Again, a cloth skirt tied around the press and nearly touching the floor improves the efficiency of the drying. The light bulbs must not be allowed to touch any combustible material.

If the volume of plant material to be pressed is very large at any one time, it is convenient to have a heated drying rack to remove moisture from the press. The most simple form of drying rack consists of a frame to support the press with a skirt and a source of heat underneath such as a number of 100-watt light bulbs or serveral kerosene lanterns. A modified version of a large laboratory oven can be used if there are provisions for venting away the moisture coming from the press.

The drying rack shown in figure 8, *A* (see p. 11) can be constructed of sheet metal or plywood. The only critical dimension is the inside width (17½ inches) to accomodate the length of the press frames, newsprint folds, and other components of the press. If the inside width is too great, most of the heated air will pass around the press instead of through it: if the width is less, it will be difficult to get the plant press in and out of the drier. Be sure to allow air space at the bottom for good circulation. It is most important to keep the press far enough above the light bulbs to avoid a fire. The amount of heat can be regulated easily by unscrewing one or more of the light bulbs.

A final device to use when a large number of specimens must be processed is not necessary but is very convenient. The drawing in figure 8, *C* (see p. 11) illustrates a stacking aid so that materials being loaded in a press are neatly positioned and tilted into a corner, lessening the danger of the pile's collapsing just as the last specimen is placed on the stack. The dimensions of the stacking corner may be varied to suit personal preference, but it must be remembered that both wedges must be cut at the same angle so that the base will set squarely on the floor or table. If press straps are laid in place with the bottom press frame before starting to stack specimens, the completed press can be closed for easy removal from the corner.

#### *Pressing Problem Plants*

Because there are many problems that will be encountered when preparing a wide range of botanical specimens, detailed solutions for specific problems will be discussed in this bulletin, beginning on page 15. However, a few problems will be encountered when preparing specimens in the Temperate Zone and solutions to these problems will be suggested here.

One of the largest groups of plants, percentagewise, in the Temperate Zone flora is the gress-sedge complex that covers vast areas of meadow, roadside, and marsh. Although it is unlikely that the beginner will attempt to press these kinds of plants initially, he will soon become aware of their prominence. All collections of grass and sedge plants should include the underground parts so that stolons, rhizomes, and roots may be seen. Since a large part of the taxonomy of these plants is based on the fruiting inflorescence, it is very important to choose specimens that have at least a few nearly mature fruit. The stems of grasses and sedges are often slender and wiry. Leaves are generally numerous and often they are long and flexible. This combination of characteristics leads to untidy specimens with stems and leaves protruding from the press in all directions.

To corner the errant ends on such material, lay the base of the plant at the bottom of the double fold of newsprint and straighten out the leaves and stems beyond the top edge of the sheet. Lay a stiff object (stick, machete edge, cardboard) across the leaves and stems within the area of the press sheet, and fold the top of the plant across this to the bottom. While still holding this fold in place with one hand, slip a previously slit paper strap over the fold (fig. 9). Some collectors make a slit in the press sheet into which the folded stem and leaves are inserted. The folding process can be repeated until the whole plant is on the press sheet. It is unwise, though, to use more than three folds on a specimen. If a plant is so tall that it requires more folding, it should be cut into two or more portions. The first herbarium sheet of the series will then display the basal portion of the plant and the second sheet will display the top and inflorescence of the plant.

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FIGURE 9.—Slit strap holding a folded grass specimen.

Among the common plants of marshy areas, there will be some that are conspicuously fleshy. These will generally collapse and dry to make a satisfactory specimen without special treatment if the press driers and corrugates are changed frequently enough. Parts of a few fleshy plants, for example, the outer hood (spathe) over the clublike flower mass of the skunk cabbage (*Symplocarpus foetidus*), are crisp when fresh and break in the press. The final specimen bears little resemblance to the plant seen in the field. To prepare specimens of this kind, cut sections to show important features and dry the sections in the usual way. Drying will be facilitated by dipping the sections in formaldehyde solution, alcohol, or boiling water to kill the cells and permit moisture to escape quickly. If the final specimen does not allow the botanist to reconstruct the plant part, it should be supplemented by a sketch or photograph of the plant before it was sectioned. For success with specimens of this kind, the driers must be changed as frequently as they become moist (once a day initially).

Among the first plants collected by the novice are those with large, colorful flowers. Many large flowers will dry quickly and retain color well. A few, like the day flowers (Commelinaceae), deliquesce (melt away or become liquid) in the press. Other large flowers, including the morning-glories, iris, and lilies become so thin that it is almost impossible to remove the specimen intact from the pressing sheet. If tissue paper is placed above and below the flower as is goes into the press, the flower can usually be peeled from the tissue without damage. If the specimen can be hardened by a quick dip into a solution of formaldehyde, there will usually be no difficulty in preparing a satisfactory specimen of difficult-to-press flowers, but formaldehyde may not be available to the casual collector.

Some plants produce fruits that are too large and fleshy to be placed directly into the press. Large, hard fruit like walnuts are easily dealt with by spreading them out on a dry surface for a few days. Large, fleshy fruits require a similar technique to that used for fleshy plants like the skunk cabbage, discussed above. Because there will be shrinkage, large fruit should be measured and then cut so that longitudinal and cross sections may be dried in the press. To prevent sticking, use a piece of thin, oiled or waxed paper, barely larger than the fruit section, on either side. Too large a piece of oiled or waxed paper will prevent the escape of moisture and lead to the development of mold on the specimen. Tissue paper can sometimes be used successfully, but it may become so firmly imbedded in the cut surface that it cannot be removed. Again, the use of a fixative to accelerate the drying is recommended.

## SPECIAL METHODS FOR PREPARING HARD-TO-PRESS HERBARIUM SPECIMENS

The collecting method described on pages 3 to 15 is the one most generally used, particularly by the average collector. The equipment is inexpensive and easy to handle although it may become bulky if a large number of specimens must be processed. To accommodate special problems and to process collections under difficult climatic conditions, a number of special methods have been developed.

### Wet Collection for Field Use

Originally developed in the Old World Tropics by European botanists, the use of preserving fluids has seldom been extensively practiced by collectors in temperate areas. Their use can be effective because they enable the collector to eliminate a large amount of the paraphernalia ordinarily carried into the field to dry specimens.

#### *Preserving Fluids Used*

Several preserving fluids have been recommended in the last few years. Moore (*17*) advocated the use of hydroxyquinoline sulphate (1 percent aqueous solution). Specimens are trimmed as usual and placed in press sheets separated by a drier. After the material has been wilted for a period (overnight is suggested), the specimens are removed from the sheets one by one and dipped into the preservative. The specimens are replaced wet in the press sheets, which are then bundled into a package of convenient size between corrugates, tied, and wrapped in waterproof sheeting (rubberized cloth or plastic sheeting). Since this solution has proved suitable to preserve fresh flowers and fruits for several months in glass containers, plant specimens in sheets would probably keep satisfactorily as long as the cover of the package was intact and the preservative did not dry out. However, the staff of the National Arboretum has recently found that preservation in hydroquinoline is less satisfactory than in other fluids.[2]

After the bundle has been transported to a central base or to its final destination, it is opened and the wet press sheets are placed in a plant press between driers and corrugates and dried in the usual manner. Moore states that the solution is "most satisfactory" without noting its effect on the color of plant parts.

Thieret (*27*) found that the hydroxyquiniline solution does not kill plant tissue quickly enough to prevent the formation of abscission layers, so that petals and leaflets tend to drop. The material is apparently nontoxic and does not attack animal skin, so it is safe to handle. In addition, the chemical is carried in powder form, so a considerable amount weighs little.

Hodge (*12*) has used and recommends alcohol as a general field preservative for herbarium specimens. After the plants are placed in press sheets, the sheets are moistened with locally available distilled alcohol and packed into a waterproof container. In this technique plant specimens are not pressed beforehand. The container mentioned by Hodge was a metal box with a lid sealed into place with surgical tape, which was then waxed to improve the seal. Again, as long as the seal was tight, the speci-

[2] Personal communication.

mens remained moist and pliable although preserved. After arrival at a central point, the sheets were placed in a press and dried in the usual manner.

Because the alcohol content of most distilled beverages ranges between 30 and 50 percent, preservation of plant material is assured. Alcohol causes many color changes in the specimens, so field notes have to detail colors carefully. Handling alcohol-preserved press sheets tends to dry the skin. Alcohol kills plant tissues immediately, preventing the formation of abscission layers and dropping of parts. Because alcohol is usually available locally and generally quite inexpensive, it does not have to be transported very far. Unfortunately, if the bundle of specimens is not properly sealed, mold will develop on the specimens.

Schultes (*24*) discusses the use of formaldehyde as a field preservative. Plant specimens are prepared and placed in the press overnight. Originally, Schultes dipped each specimen into a solution of two parts of commercial formaldehyde diluted with three parts of water. I find that the folds holding the specimens need only to be moistened at the center underneath by a quick dip into the solution. Other botanists immerse a stack of folds with specimens in a stronger solution (1:1) of formaldehyde. The stack of specimen folds are then tied tightly between corrugates and wrapped in waterproof sheeting or placed in an airtight plastic bag to prevent drying. I have stored specimens for as long as 6 months in this way. When it is convenient, the folds are placed in a plant press and dried in the usual way at a central base or at the final destination of the plant material (fig. 10).

The folds of newsprint need only be dampened with the formaldehyde solution because preservation is accomplished by formalin gas. Newsprint that is thoroughly sodden becomes pulpy and it is virtually impossible to separate the individual sheets. Furthermore, too much fluid adds much weight to the bundle.

The use of formaldehyde has several disadvantages. It, like alcohol, must be carried in liquid form, A dry chemical, frequently called paraformaldehyde, has been suggested as a more easily carried source of formalin. At the time I first considered using a wet-collecting technique, I asked a chemist to recommend the

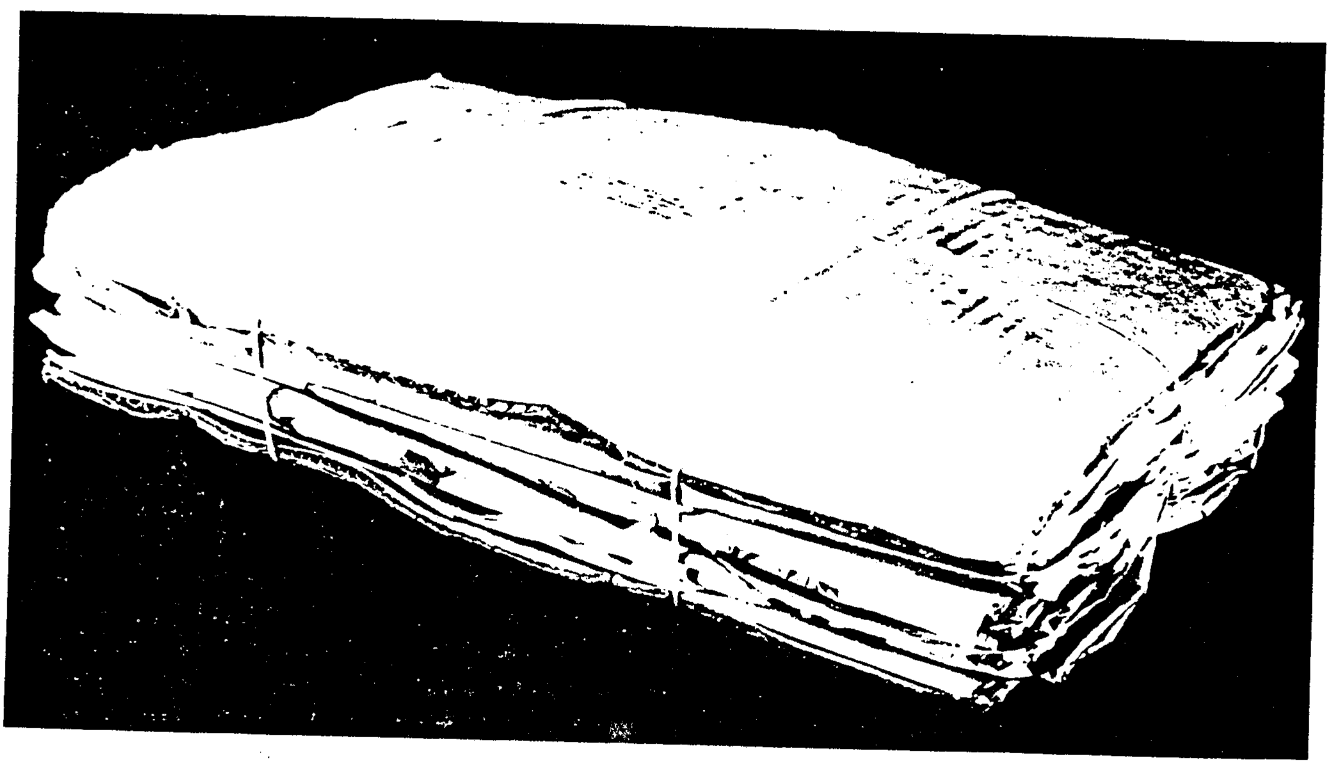

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FIGURE 10.—Bundle of specimens reinforced with corrugated cardboard and tied for storage or shipment.

best method of preparing formalin from the powdered chemical. His experiments proved that a formalin solution of usable strength could be obtained only by use of heat at a controlled temperature and buffering of the solution to a precise pH, conditions that are nearly impossible to obtain in the field. Formaldehyde is an indiscriminate preserver of all biological material and will damage the skin of an incautious user. If rubber gloves are not available or are too awkward when placing the wet sheets in the press, a heavy coating of petroleum jelly on the hands will prevent damage. When formaldehyde is used in an unventilated area, fumes cause the eyes to tear and can cause inflammation of the nose and throat. Formaldehyde changes the depth of the green color of leaves and alters some flower colors completely, so good color notes must be taken before the plants are pressed.

A number of unjust charges have been leveled at the use of formaldehyde as a preservative. Color changes are not as marked as many people have stated. The color of specimens in the herbarium fades with time anyway, so this is not a serious defect provided color notes are accurate. The statement is often made that formaldehyde makes material brittle, probably because it is known to harden animal tissue. This is not true. Before plant specimens preserved in formaldehyde are dried, they remain flexible and crumpled leaves and petals can be straightened at will. After they are dried, the specimens are no more brittle than those prepared by any other method. In fact, specimens of loranthaceous plants, which are notoriously brittle when dried without a preservative, hold together very well when placed in a solution of formaldehyde before pressing.

Fosberg (*9*) recommends the use of a solution of one part of 40 percent formalin to two parts of 70 percent alcohol to preserve plant specimens. He paints this onto the specimen with a 2-inch paintbrush. The advantages to be gained are said to be better wetting of the specimen and better penetration of the preserving fluid. However, the disadvantages of both preservatives are retained as well as the further disadvantage of having to transport another liquid.

Still other liquids are used to preserve plant material. Kerosene and gasoline, both of which may be more readily available than formaldehyde, are used as dips to kill plant tissue and to aid in its drying and preservation. With either of these liquids, the specimen is dipped, drained, and placed in the press sheet without the addition of enough liquid to wet the paper. Obviously, artificial heat cannot be used to hasten the drying until all fumes from the preservative have evaporated. The use of flammable organic solvents for preserving is hazardous because of fire danger and because they may constitute a health hazard in unventilated areas; thus any of the previously mentioned preservatives are preferred over kerosene and gasoline.

### *Equipment Needed*

Mention has already been made of the press frames, driers, and corrugates needed when several of these preservatives are used. Because the bundles of plants are packed wet, only enough press supply to hold specimens for 24 hours needs to be carried into the field. A collector preparing 5 to 10 duplicate specimens of every number will rarely be able to collect and prepare more than 100 numbers per day, even with good field assistance. When working alone, a collector will usually find that about a third of the amount will provide a hard day's work. Far fewer numbers of difficult-to-prepare specimens can be handled. The amateur collector or the collector who is preparing only an occasional specimen in conjunction with another project will rarely need press space for more than 50 sheets of plants per day. This brief estimate of daily press capacity can serve only as a guide and must be adjusted by experience.

In general, then, enough driers are needed to furnish at least one for every specimen put in the press. Enough corrugates are needed to allow two on each side of every large woody specimen inserted between more delicate, herbaceous specimens or one per specimen when all of the material going into the press is woody and intractible. Because corrugates will be used as covers for bundles for storage, extra corrugates must be allowed for this purpose. One sheet of folded newsprint is needed for every specimen placed in the press. Finally, two press frames and two straps or ropes are needed for every 60 to 90 thin specimens or for every 50 or fewer woody specimens. Under some circumstances, it may be possible to pack more specimens than this into a single press, but only a few woody specimens make uneven press piles that tend to squirt out the side when pressure is applied.

For field use, nothing can exceed the value of plastic containers for handling liquids. The use of all these preservatives requires the mixing of solutions or the transporting of liquids. Since a gallon or less of prepared solution is needed for most days' work, a 1-gallon plastic jug is required to mix and store the liquid. For dipping sheets, a plastic photographic tray of the size used in processing 11- by 14-inch prints is convenient. This size allows the underside of a fold of newssheet to be thoroughly wet. When formaldehyde or alcohol is carried into the field, metal or plastic stock containers should be used. Usually, the containers furnished by the manufacturer will be accepted by surface carriers for transport. If supplies must be shipped by air, regulations require that substances like formaldehyde be packed in small quantities and especially marked. In this case, frequently it is more convenient to repackage the stock liquid in plastic quart bottles. Advantages of the repacking include ease of packing, the lack of breakage when supplies must be transported on pack animals, and the high value of empty plastic bottles among the rural people of most countries outside the United States.

Because bundles of specimens must be kept moist until ready for final drying, a supply of liquidproof sheeting or large plastic bags must be available. Plastic bags large enough to hold several bundles of 100 to 150 specimens each can be furnished by dealers in polyethylene tubing. Tubing 4 mils thick and 30 inches wide can be ordered cut to the desired length and sealed at one end. Large plastic bags immediately lend themselves to additional uses as collecting bags in the field, ground covers, or even temporary raincoats with holes for the arms and head cut in the bottom.

When it is necessary to dry specimens prepared by the wet-collecting method using formaldehyde, it is desirable to have an enclosed drier from which the fumes can be vented to the outside. Plans for a very satisfactory drier with a temperature controller are shown in figure 11. In the homemade drier from which these plans were devised, the original cabinets were wooden, half-size herbarium cases from which the backs were removed so that they could be joined to form a continuous chamber. Heat was provided by electric air heaters with fans controlled by a temperature controller so that the heat underneath the press never approched the boiling point of water by many degrees. A small fan in the vent stack ran continuously while the drier was in operation, ensuring that the air moved steadily through the press.

## Suggested Techniques for Preparing Hard-to-Prepare Herbarium Specimens

Although the amateur who collects plants for pleasure is not likely to wish to collect many of the troublesome plants discussed below, he may find here a hint to help him in preparing specimens of some of the less commonly collected plants. For instance, discussion of the treatment of succulent xerophytes (see p. 20) will apply equally well to any other succulent plant. To avoid repetition, this section will be divided into discussions of a general problem to be met in several groups of plants.

### *Floating or Submerged Aquatic Plants*

It is singularly difficult to prepare representative specimens of many floating and submerged aquatic plants because the entire plant body is normally supported by water and it tends to collapse almost completely when removed from water. To this is added the difficulty of straightening leaves that are divided into many filiform segments. To reduce the amount of arranging to a minimum, float aquatics in a large, shallow vessel or tray (fig. 12). Slip a sheet of paper (preferably a good grade of bond) under the specimen and then gently lift it as nearly level as possible so that the water drains away slowly. If this is carefully done, the plant will be well distributed across the paper and most of the leaves will be spread. If the first attempt is unsuccessful, the plant and sheet may be returned to the water. When ready for the press, the sheet of paper bearing the plant specimen is put into a fold in the usual

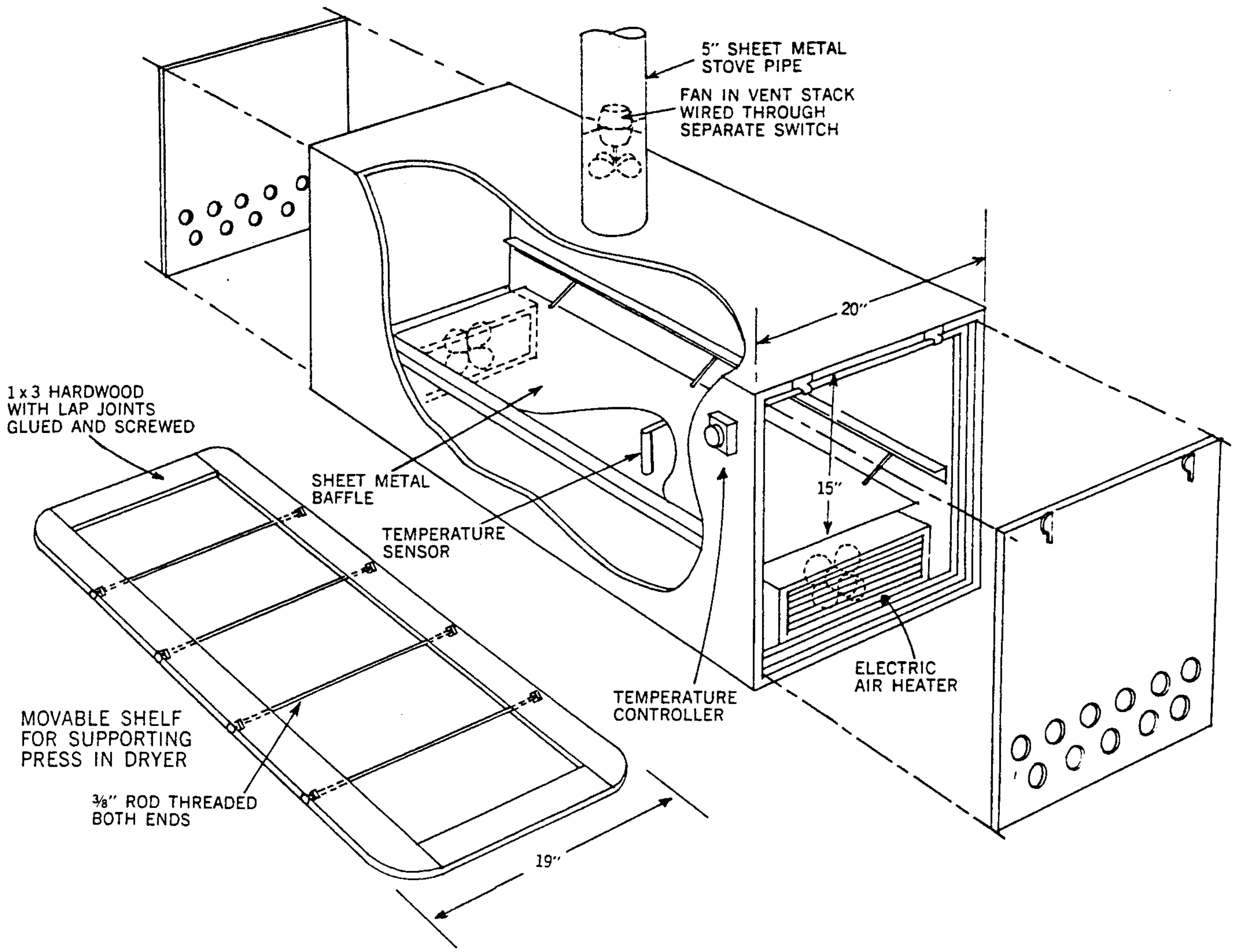


FIGURE 11.—Design for a completely closed plant drier with forced draft ventilation for drying specimens preserved with alcohol or formaldehyde. The stack should be vented to the outside.

way. If the specimen appears to be mucilaginous, as many aquatic plants tend to be, either tissue or thin waxed or oiled paper may be laid over the specimen before closing the fold to prevent the specimen from sticking to the newsprint. The specimen is then dried in the press routinely. When removing the specimen after drying, peel the covering protective paper carefully, but allow the specimen to adhere to the underlying bond paper and mount the specimen on the herbarium mounting paper without disturbing the specimen.

If many aquatic plants are to be collected, a rectangle of 1/4-inch hardware cloth cut to about 11 by 15 inches can be used to lift plant specimens from the water directly on a piece of paper. The paper is slipped into a newsprint fold and dried without disturbing the specimen.

### *Plants With Large Parts*

Sometimes the most nearly representative specimen of a plant will include parts that are either too long and wide or too bulky to be placed in the press. (See Appendix I for plant features to be illustrated by prepared specimens.) In some instances, as with pine cones, the structure is woody. This causes no difficulty because the part that doesn't fit may be removed from the branch, tagged with the same field number as the pressed specimen, dried, and later placed in a box for filing. If it is desirable and facilities are available, the back half of a pine cone may

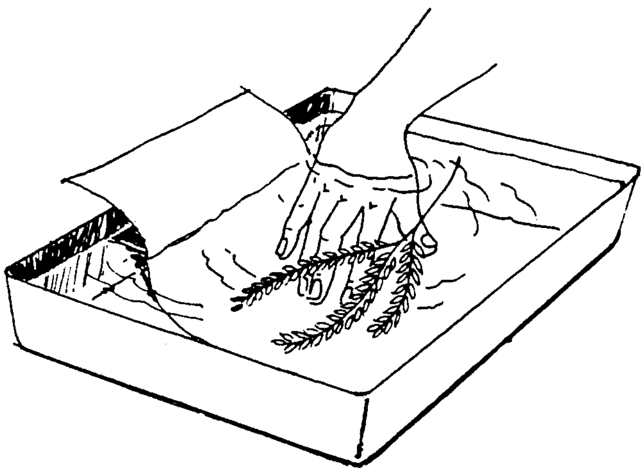

FIGURE 12.—Use paper to lift submerged aquatic plant specimen.

be removed with a fine-toothed saw so that the cone may be left attached to the specimen without disrupting the press unduly. Unfortunately, not all large plant parts are so easily made into specimens.

LARGE FOLIAGE.—The typical foliage of a number of plants is larger than the 12- by 16-inch herbarium mounting paper will accommodate. This is particularly true of tree ferns, aroids, bananas, gunneras, and palms, the last of which will be discussed separately. (See p. 24.) In general, leaves are bilaterally symmetrical, so one-half of the leaf may be cut away to one side of the midrib or central leaf vein without destroying its value as a specimen. If the rest of the leaf is still too large to fit the press fold without bending more than once, it will probably be necessary to cut the lamina and petiole into several pieces, pressing each in a separate fold. (See p. 6.) All folds must bear the same field number, and if there is any chance that the sections cannot be oriented so that they may be reassembled to show the original outline of the half-leaf, these folds should be serially marked with letters or with Roman or arabic numbers in parentheses. It is always better practice to photograph or sketch the leaf before dividing, making sure that a scale is included, so that the original dimensions can be calculated.

LARGE FRUIT.—Many plants bear fleshy fruit that either does not press easily or does not press at all. Since the shape of irregularly shaped fruit is very difficult to describe, such fruit should be photographed or sketched with a scale and color notes recorded. The fruit can then be divided into both longitudinal and cross sections, with sufficient outer surface preserved to clearly show the character of the skin (fig. 13). These sections are placed in the press with tissue or oiled or waxed paper on either side so that the section will not adhere to the newsprint fold in which it is dried. The protective paper should be cut as small as possible because large sheets of oiled paper on either side of a section will effectively seal around the section and prevent the moisture from escaping. Sections of this kind not only show the general shape and dimensions of the fruit, but also show the size and placement of the seeds.

BULKY ROOTS OR STEMS.—On occasion it will be necessary to prepare specimens of plants whose roots or stems are modified into storage areas and are generally greatly thickened. Because these will bulk unnecessarily large in the press, they also should be photographed or sketched with a scale and divided into sections for pressing. Frequently tissue of this sort does not present the problem of stickiness encountered with fruit, so protective paper on the sides of the sections will not always be needed. If the piece to be preserved is woody, it can be dried whole and later sectioned with a saw. In this case, the specimen must bear the same number as the portions of the plant placed in the press.

### *Succulent Xerophytes*

The largest percentage of succulent plants, i.e., plants in which the stems or leaves, or both, are highly modified to store quantities of fluid, are found in semiarid or arid regions around the world. Thus, they are xerophytes. Even the hobbyist is tempted to press some of the bizarrely shaped plants, many of which bear large, colorful flowers. Succulent plants are especially adapted to take up and retain fluid for long periods and this capacity is maintained in the plant press. The family Cactaceae in the New World is noted for members that are resistant to drying.

A camera or a facility for making accurate drawings is essential to the proper collection of many succulent plants. A scale must be included with the illustration because the plant tissue

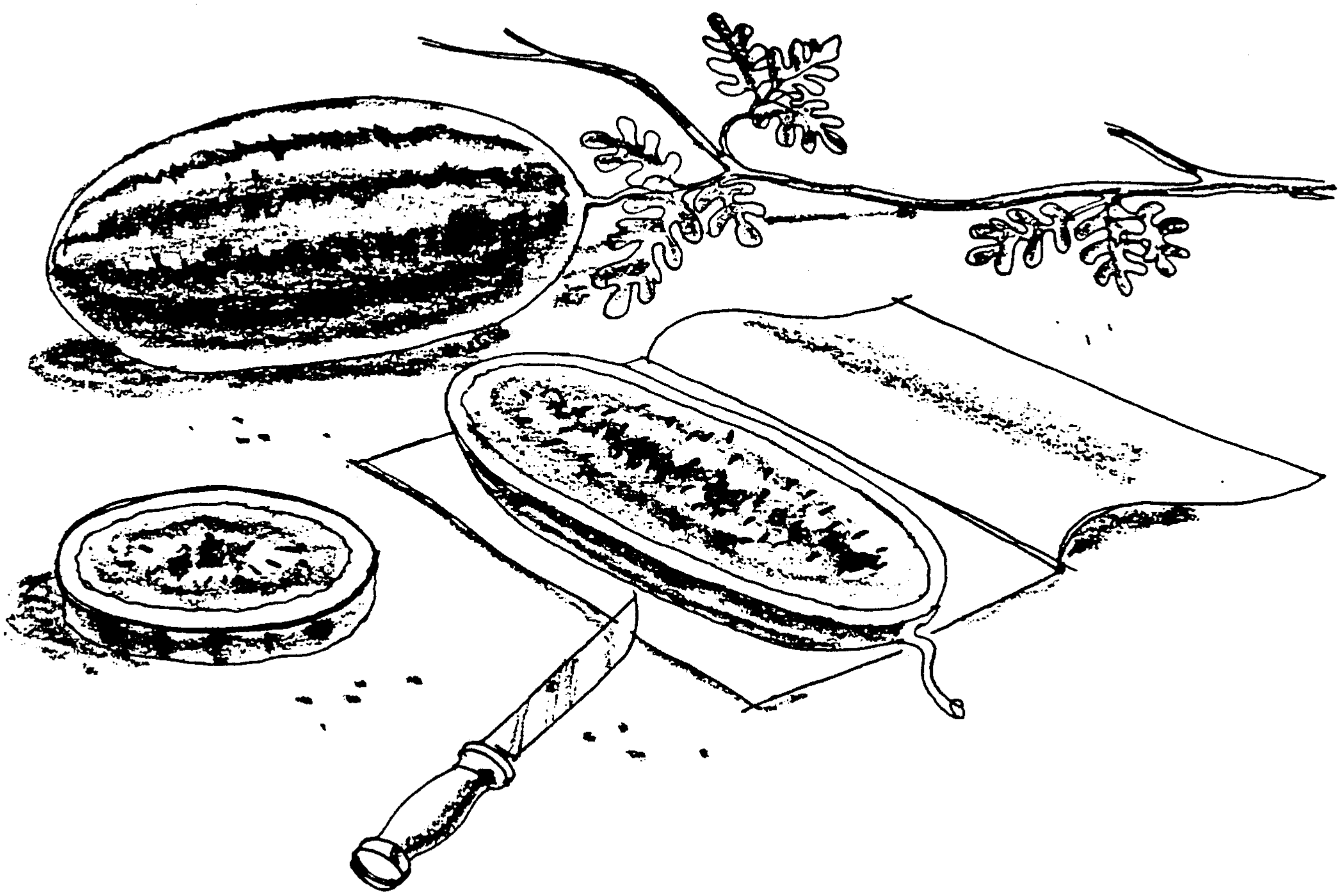

FIGURE 13.—Make longitudinal and cross sections of fruits that are too large to press entire.

shrinks very much with drying. Along with the illustration, color notes are needed, particularly for flowers and fruit. A general habit illustration may not always be essential to the identification of the plant, but it frequently is useful because many of the larger succulent plants have characteristic forms of branching.

Once the illustrations have been made, sections of the plant bearing flowers or fruit are cut to a length that will fit into the press (fig. 14). Large plants like the arborescent cacti and euphorbias have stems much too thick to be pressed whole; these must be sectioned both crosswise and lengthwise, taking care to show at least one section with the point of attachment of a flower or fruit. Because the reproductive structures may also be fleshy, they too must be split in half or sectioned. Whenever the fluid in the sections appears to contain a latex or mucilaginous substance, it is best to use a protective paper cut to the size of the specimen to keep the section from sticking to the newsprint fold.

Because most succulent plants lose their moisture slowly, specimens dry very slowly and mold badly. It is, therefore, essential that such specimens be treated with formaldehyde, alcohol, or other organic preservative or solvent to kill the tissue and allow the specimen to dry as quickly as possible.

Cacti of the pricklypear group with stem joints composed of flat pads present a more difficult problem because cross sections are not necessary and the pads frequently appear to be thin enough to fit readily into the press. Unfortunately, such specimens not only refuse to dry but also sprout readily, even after months in the press. Although many of the species of this group are equipped with an armament of numerous spines, the best method of preparing specimens of the pad is to cut the pad in two, parallel to the flat sides. This provides two specimens of one-half the thickness of the original pad. If these are then killed by immersion in formaldehyde, alcohol, or other organic preserv-

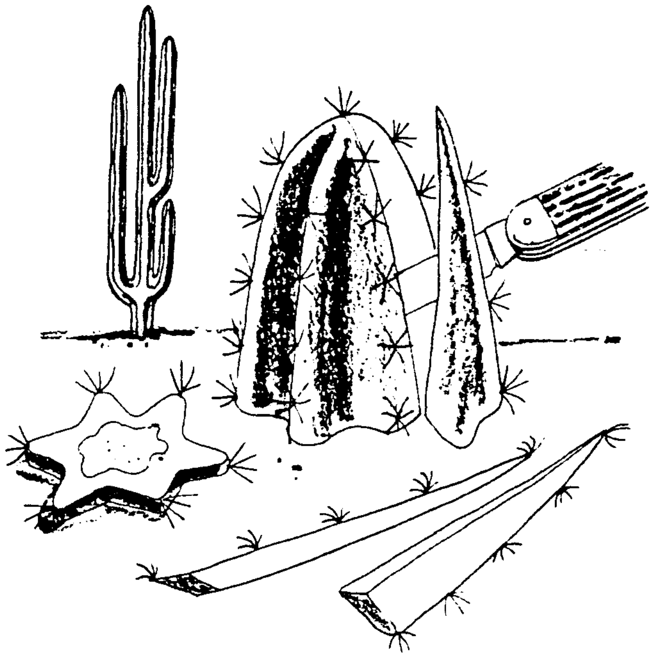

FIGURE 14.—Large cacti are cut in cross section and a single longitudinal rib.

ative, they will dry quickly and completely. Fruit is critical for the separation of some species in the pricklypears.

Members of the lily and amaryllis families with arborescent or shrubby habits frequently have large fleshy leaves borne in rosettes. Agaves bear some of the largest leaves of plants of this kind and, in addition, agave inflorescences may be 30 feet tall and 6 to 8 feet in diameter. As with other specimens, photographs or sketches, with scales, of the plant habit, a leaf, and the inflorescence, along with color notes, will eliminate much note taking. The inflorescence must be cut and representative sections of the stalk, branches, flowers, and fruit placed in the press. The flowers are particularly important to an understanding of the classification of this group of plants. Care should be taken to assure that the pieces of the plant chosen for preservation can be related to one another and to the illustration of the whole plant or inflorescence.

Leaves must be considerably reduced in bulk but the character of the margin and the shape of the whole leaf are important in classification. To preserve as much of the leaf as possible, one of two methods may be followed: (1) The entire top surface and margins of the leaf may be cut away from the back of the leaf (fig. 15); or (2) the entire center of the leaf to within 1 inch of the margin and basal end may be cut out (fig. 16). The first method is very good for long, narrow leaves because the leaf can then be folded several times to fit into the newsprint press paper. The stout fibers present in the agave leaf will act as hinges so the leaf may be unfolded to its full length when it is desirable to examine it in the herbarium. The second method is preferable for short, broad leaves. As with any succulent plant part, immersion in a preservative will kill the tissues quickly and allow the specimen to dry rapidly and evenly.

***Succulent Mesophytes and Hydrophytes***

Surprisingly enough, many mesophytes (plants that grow under medium conditions of moisture) and hydrophytes (plants that grow in water) are succulent to the extent that some care must be used in their preparation as herbarium specimens. The succulence of most of these plants is confined to the rootstalk, stem, or leaf petiole, as in members of the ginger or the banana family. If the plant is particularly large and must be divided into a number of parts for pressing, the usual record of the habit

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FIGURE 15.—Cutting away entire back of agave leaf so that it can be pressed.

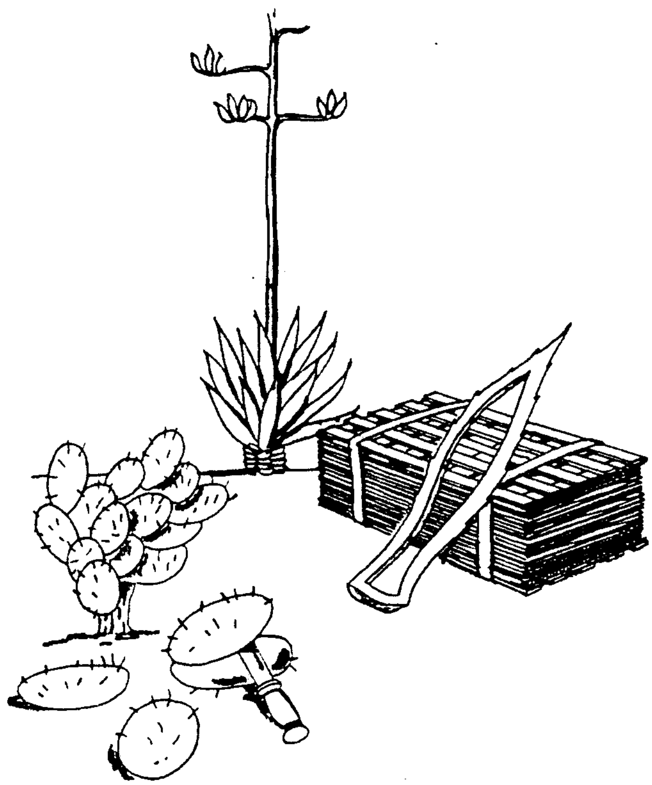

FIGURE 16.—The entire center is cut out of short, wide agave leaves.

and the size and shape of parts by means of photographs or sketches is needed. In general, the thick member is then split down the middle and both halves are pressed. Immersion in a preservative or solvent will insure quicker drying and better specimens. Again, good color notes are essential.

The orchids present some special problems. Many of the orchids have fleshy stems or pseudobulbs, which are not quite thick enough to warrant splitting but which are very retentive of moisture and thus do not dry well. Some of the orchids have large flowers with fleshy petals of unusual shapes. These neither look much like the unpressed flower when they are removed from the press, nor are they very quick to dry; and they frequently mold. Drying of the stems and pseudobulbs can be hastened by cutting a series of small slits in the outer surface before pressing. Flowering material is best prepared by immersing the specimens in formaldehyde or alcohol. The drying time is much shorter, there is no molding, and the preservative helps retain the shape of the flower parts. Photographs and color notes are necessary for parts with unusual shapes or sizes.

#### *Plants With Deliquescent or Fragile Flowers*

The flowers of many plants are difficult to preserve so size and shape of the parts may be seen and studied. Many of the day flowers (Commelinaceae) are deliquescent (tend to melt away or become liquid by attracting and absorbing moisture from the air) and break down completely unless they are picked very early in the day and pressed immediately. Flowers of iris, lilies, hibiscus, and many other plants with large petals or thick texture, or both, tend to either rot in the press or stick to the fold in which they are pressed, and then the petals tear as they are removed. Pieces of tissue paper cut to the size of the flowers will facilitate their removal from the press sheet. If color retention is very desirable, the moisture can be rapidly removed from a single flower by placing it between blotting paper pads and heating it with pressure by an ordinary electric clothes iron. However, this is not practical for a number of specimens. The most practical method of preparing such flowers is by immersing the specimen in a preservative before pressing. Many pigments will not be changed appreciably by this and a much better preserved flower will result. It should be noted that white in flowers is a lack of pigment; consequently, when the physical structure of the tissue is changed by drying, its light-reflecting qualities change so that white areas then appear tan or brown.

#### *Plants of the Pineapple Family*

Species of plants belonging to the pineapple family (Bromeliaceae) present a rather unique problem in that the plant body is generally a rosette of leaves that is frequently large and nonsucculent but very resistant to drying. This rosette is topped by an inflorescence often much too large to fit easily into a press fold. The procedures for sectioning previously outlined do not work well on rosettes. For these plants, the best procedure is to peel the rosette apart, selecting representative leaves for the press (fig. 17). The stem and inflorescence that remains then can be placed in the press as it is or if it is too large, can be split from the base to the

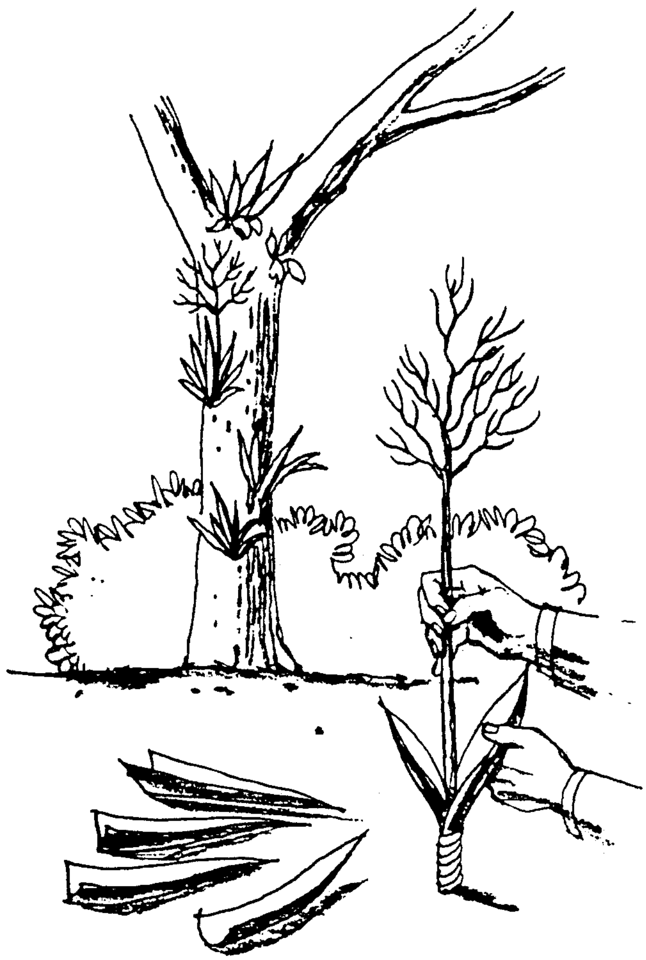

FIGURE 17.—Rosettes of species of the pineapple family are pulled apart and individual leaves and inflorescence are pressed.

apex yielding two specimens of about equal size. Some species of the family produce very large inflorescences that must be handled by sectioning, like the agave inflorescence. (See p. 22.) Flowers are generally more important than fruit for identification of members of the Bromeliaceae. As noted before, whenever a plant must be divided or sectioned, photographs or sketches with scales should be made first.

### *Plants of the Palm Family*

Preparing plants of the palm family (Palmae) is difficult for the field botanist in tropical areas. Some palm species are small plants of the forest floor and will fold to fit into the press sheet. But by far the largest number of palms bear leaves that can only be described as gigantic. Frequently, the inflorescence is as large as the foliage. Much of the difficulty encountered in the classification of palms stems directly from the inadequacy of the specimens available for study. L. H. Bailey (*2*) discussed this problem and the preparation of palm specimens; his recommendations are still valid.

Before attempting to collect palm specimens, the collector must become thoroughly familiar with the operation of a camera. The plant furnishing the specimen should be photographed before any part is cut. Each frond and inflorescence destined for the press must be photographed before it is divided. Every piece of an individual tree must be tagged with the same field number because it is generally necessary to cut each leaf or inflorescence into many small pieces to get them into the press. Like other large leaves, palm fronds are bilaterally symmetrical, so one-half of the leaf can be trimmed away. The rest must be divided into portions, taking particular care to make good specimens of the top and base of the frond and the base of the petiole as well as intermediate samples from the rest of the leaf. In many palms, the inflorescence emerges from a sheath or series of sheaths. These are important to the classification of the plant and must be preserved along with portions of the inflorescence showing both male and female flowers, fruit, and enough of the basic structure to show the general configuration and method of branching.

Because both the bromeliads (see p. 23) and the palms are resistant to drying, they are much better preserved if they are placed in formaldehyde or alcohol before they are pressed. If there are many of these or similar plants to be processed, it is strongly recommended that a preservative be used for all specimens and the final drying of the specimens be delayed until they can be handled at a permanent installation with drying facilities employing heat. The habitats in which many of the hard-to-press plants grow are subject to hard-to-predict weather that frequently makes field drying very uncertain.

### *Bamboo Plants*

The woody grasses commonly called bamboo are another distinctive group of plants that causes the collector considerable difficulty. The classification of the bamboo species depends upon vegetative structures because many bamboos flower only once in a lifetime and then promptly die. Photographs of the clump before specimens are taken and photographs of parts before they are divided for the press are needed. A mature culm is then cut to obtain the mid-culm sheaths and branch complement and a specimen with two nodes and the internode. On all of these, the number of the node above the ground should be recorded. The rhizome should be dug and photographed so the manner of branching is apparent; sections are then preserved. Because many of these parts will be too large or too bulky to fit into a plant press, the collector should mark the separate pieces with the field number and a serial section number before dividing the plant so the specimen can be reconstructed. If flowering material is available, a series of specimens showing the range of variation of the parts of the inflorescence should be collected. Young shoots should also be collected. Since two different species of bamboo in adjacent clumps may intergrow, care must be taken to collect all portions of the specimen from the same plant. Immersing in a preservative will kill the tissue and result in quicker, more uniform drying of the specimens.

***Screwpines***

Another group in which special collection problems occur is the genus *Pandanus*, more familiarly known as screwpine. The group is widely distributed in the Old World Tropics. A better understanding of the relationships of the species of the genus depends upon improving the quality of collections of the group.

Screwpine, like a number of other plants, is always dioecious as far as is now known. (See Appendix II.) Whenever members of this group are collected, an effort should be made to find both sexes under circumstances that indicate the relationship of the two plants. If male plants cannot be demonstrated to be associated with female plants in the same colony, they are of little value, because the more critical determinations are made on the basis of the fruit.

The fruits of the female plant of some species may be small enough to be left on the plant when it is placed in the press. Many species, though, bear very large heads of fruit that may be solitary or in spikes. As with other large plant parts, fruiting heads should be photographed or sketched, preferably with a scale, before they are divided. The heads frequently must be split in half longitudinally before drying. When mature, the fruits are generally soft and fleshy and they will dry more quickly if immersed in a preservative. If supplies are available, representative parts may be bottled in preservative, but most field collectors will find that drying the representative parts is sufficient.

Screwpine leaves are usually borne as a spiral of lanceolate leaves on a thick stem. Disks of the stem should be cut free and the entire leaf, including the sheathing base and the unbroken tip, folded into the press sheet. Photographs or sketches of the vegetative parts should be made before the leaves are removed.

In addition to the foliar and inflorescence material, a sample of the mature bark and sections of prop roots should be included in the collection. As with all collections in which diverse samples are to be handled in different ways, it is imperative that all parts of a collection be identified with the collection number in such a way that parts of the collection do not go astray.

***Arborescent Plants***

Although many of the suggestions that have been discussed in relation to specific problems apply generally to other arborescent (treelike) species, it is worthwhile to emphasize some suggestions.

Among the foremost of these is the recording of the overall aspect of a very large plant. Identification must, of necessity, be based on the small sample placed in the press, but collectors today have little excuse for ignoring the habit of large plants. Photographs of the tree to show it from base to top are needed to demonstrate many features unless the collector wishes to write lengthy notes describing the appearance of the base, the character of the trunk, the method and density of branching, and the size and shape of the crown. If at all possible, detailed photographs of the bark, base, and branching are frequently helpful and will provide information that is lacking on most older herbarium specimens.

At times, photographs or sketches showing the buttressing of the base of a tree, bark details, or cauliflory can save the collector many tedious notes. Unless the collector works with a restricted group of plants over a long period of time, details observed in the field are soon forgotten. Unfortunately, color films in general use cannot be relied upon for color notes because the dyes either reproduce the color inaccurately or fail to reproduce it completely.

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# APPENDIX I

## General Guide to Features to Be Illustrated by Prepared Specimens

Not all members of the following families will have to be treated as suggested. Although either fruit or flowers may be critical for the identification of some groups, if available, both should be collected.[1]

| Family | Dimorphic foliage | Flowers | Fruit or sporangia | Rootcrown | Section | Use fixative |
|---|---|---|---|---|---|---|
| Acanthaceae | | X | | | | |
| Aizoaceae | | X | | X | | WP |
| Amaranthaceae | | | X | X | | |
| Amaryllidaceae | | X | | X | Lf,In | WP |
| Annonaceae | | | X | | Fr | Fr |
| Aponongetonaceae | X | | | | | |
| Aquifoliaceae | | | X | | | |
| Araceae | X | | X | | Lf,In | WP |
| Araliaceae | | | X | X | | |
| Araucariaceae | | | X | | X | Lf |
| Asclepiadaceae | | X | X | | X | |
| Begoniaceae | | X | X | X | | WP |
| Betulaceae | | | X | | | |
| Bignoniaceae | | X | | | | |
| Bombaceae | | X | | | | |
| Boraginaceae | | | X | X | | |
| Bromeliaceae | | X | | | Lf,In | WP |
| Burmanniaceae | | X | | X | | WP |
| Burseraceae | | | X | | | |
| Butomaceae | | | | X | | |
| Cactaceae | | X | X | | St,Fr | WP |
| Cannaceae | | X | | X | | In |
| Caprifoliaceae | | X | X | | | |
| Celastraceae | | | X | | | |
| Cephalotaxaceae | | | X | | Fr | Lf |
| Ceratophyllaceae | X | | | | | |
| Chenopodiaceae | | | X | X | | |
| Combretaceae | | X | | | | |
| Commelinaceae | | X | | X | | Fl |
| Compositae | | X | X | X | | |
| Convolvulaceae | | X | | | | Fl |
| Crassulaceae | | X | | | | WP |
| Cruciferae | | | X | X | | |
| Cucurbitaceae | | X | X | | Fr | Fr |
| Cupressaceae | | | X | | | |
| Cyatheaceae | | | X | | Lf | |
| Cycadaceae | | | X | | Lf,Fr | WP |
| Cyclanthaceae | | X | | | Lf,In | Fl |
| Cyperaceae | | | X | X | | |
| Dicksoniaceae | | | X | X | Lf | |
| Dioscoreaceae | | X | X | | | |
| Ebenaceae | | | X | | Fr | |
| Equisetaceae | | | X | X | | |
| Ericaceae | | X | X | | | |
| Euphorbiaceae | | X | X | X | St | WP |
| Fagaceae | | | X | | | |
| Flacourtiaceae | | X | X | | | |
| Gentianaceae | | X | | X | | |
| Geraniaceae | | X | X | X | | |
| Gesneriaceae | | X | | X | | |
| Gramineae | | | X | X | | |
| Guttiferae | | | X | | Fr | WP |
| Haloragaceae | X | | | | | |
| Hippuridaceae | X | | | | | |
| Hydrocharitaceae | X | | | | | |
| Hydrophyllaceae | | X | X | X | | |
| Iridaceae | | X | | X | | |
| Isoetaceae | | | X | X | | |
| Juglandaceae | | | X | | | |
| Juncaceae | | | X | X | | |
| Labiatae | | X | X | X | | |
| Lauraceae | | | X | | X | Fr |
| Leguminosae | | X | X | X | | Lf |
| Lentibulariaceae | X | X | X | X | | |
| Liliaceae | | X | | X | | Fl |
| Loranthaceae | | | | | | WP |
| Lycopodiaceae | | | X | X | | |
| Malpighiaceae | | X | X | | | |
| Malvaceae | | X | X | | | |
| Marantaceae | | X | | X | | |

See footnote at end of table.

| Family | Dimorphic foliage | Flowers | Fruit or sporangia | Rootcrown | Section | Use fixative |
|---|---|---|---|---|---|---|
| Marattiaceae | | | X | | | |
| Marcgraviaceae | X | | | | | |
| Melastomataceae | | X | | | | |
| Meliaceae | | | X | | | |
| Moraceae | | | X | | Fr | |
| Musaceae | | X | | | Lf, In | WP |
| Myristicaceae | | | X | | Fr | |
| Myrtaceae | | | X | | | |
| Najadaceae | X | | | | | |
| Nyctaginaceae | | | X | X | | |
| Nymphaeaceae | | X | | | | WP |
| Oleaceae | | | X | | | |
| Ophioglossaceae | | | X | X | | |
| Orchidaceae | | X | | | | WP |
| Osmundaceae | | | X | X | | |
| Palmae | | X | X | | WP | WP |
| Passifloraceae | | X | | | Fr | |
| Pinaceae | | | X | | | Lf |
| Piperaceae | | | | | | Lf |
| Plantaginaceae | | | X | X | | |
| Polemoniaceae | | X | X | X | | |
| Polygalaceae | | X | | | | |
| Polygonaceae | | | X | X | | |
| Portulacaceae | | | | | | WP |
| Potamogetonaceae | X | | | | | |
| Psilotaceae | | | X | X | | |
| Rhamnaceae | | | X | | | |
| Rosaceae | | X | X | X | | |
| Rubiaceae | | X | X | | | |
| Rutaceae | | | X | | Fr | |
| Sapindaceae | | | X | | | |
| Sapotaceae | | | X | | Fr | |
| Schizaeaceae | X | | X | X | | |
| Selaginellaceae | | | X | X | | |
| Simaroubaceae | | | X | | | |
| Solanaceae | | X | X | X | Fr | |
| Sparganiaceae | | | X | X | | |
| Sterculiaceae | | | X | | | |
| Taxaceae | | | X | | | Lf |
| Taxodiaceae | | | X | | | Lf |
| Theaceae | | X | | | | |
| Tiliaceae | | X | X | | | |
| Turneraceae | | X | X | | | |
| Ulmaceae | | | X | | | |
| Umbelliferae | | | X | X | | |
| Verbenaceae | | X | X | | | |
| Violaceae | | X | | X | | |
| Vitaceae | | | X | | | |
| Xyridaceae | | X | X | X | | |
| Zingerberaceae | | X | X | X | Lf In | In |

[1] Fl = Flowers. Fr = Fruit. In = Inflorescence. Lf = Leaves. St = Stem. WP = Whole plant.

## APPENDIX II

### Plants With Unisexual Flowers

Some or all members of the following plant families bear male and female reproductive organs in separate flowers. These may be in the same inflorescence, on different areas of the same plant, or on separate plants. Care should be exercised to obtain specimens of both sexes if possible.

Batidaceae
Begoniaceae
Betulaceae
Buxaceae
Caricaceae

Casuarinaceae
Cercidophyllaceae
Chloranthaceae
Cornaceae
Cucurbitaceae

Cyclanthaceae
Datiscaceae
Dioscoreaceae

Ebenaceae
Elaeagnaceae

Empetraceae
Eucommiaceae
Euphorobiaceae
Fagaceae
Flacourtiaceae

Garryaceae
Gnetaceae
Guttiferae
Hamamelidaceae
Hernandiaceae
Juglandaceae

Lardizabalaceae
Lauraceae
Leitneriaceae
Loranthaceae

Menispermaceae
Monimiaceae
Moraceae
Myricaceae
Myristicaceae

Myrsinaceae
Najadaceae
Nyctaginaceae
Nyssaceae

Pandanaceae

Phytolaccaceae
Platanaceae
Proteaceae
Rafflesiaceae
Salicaceae

Santalaceae
Schisandraceae
Ulmaceae
Urticaceae
Valerianaceae

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# APPENDIX IV

## Vegetation Assessment and Classification Forms with Worked Examples[1]

1 Please note that the data listed in the worked examples are actual data. However, they have been truncated and slightly modified. This information is presented as an instructional convenience only and is not a complete series of species and releves.

# CPVAC VEGETATION RECORD

| Investigator | Date | Record No. | Relevé Number | |
|---|---|---|---|---|
| Land Ownership | Administrative Unit | Administrative Sub-Unit | State | County |
| Relevé | Relevé Location | | | |
| Slope Percent or Degree | Aspect N / NE / E / SE / S / SW / W /NW / L | Elevation (m) | Area (Ha) | |
| Georeference Coord. (Lat./Long/UTM) | | Zone ( for UTM) | Airphoto I.D. and No. | |

| Photo No. North | Photo No. East | Photo No. South | Photo No. West | Remote Sensing Ref. DBF No.s | TM | Spot or Other |
|---|---|---|---|---|---|---|
| Soil Series | | Soil Association | | Soil Color | Dissection None Low Med High | |
| % Boulder (>190mm) | % Cobble (65-190 mm) | % Gravel (3–64 mm) | % Sand (0.05-2mm) | % Silt (0.04-0.002 mm) | % Clay (<0.002 mm) | Soil Texture |

**Circle:** Rockpile / Bajada / Drainage Channel / Valley Bottom Fill / Side Slope / Lower Slope / Mid Slope / Upper Slope / Ridge / Floodplain / Interfluve / Slickrock / Terrace / Mesa /Butte/ Cliff / Talus / Sand Dune or Sheet Scree / Cinder

**Circle:** Alluvium / Conglomerate / Sandstone / Shale / Limestone / Dolomite / Serpentine / Marble / Schist / Gneiss / Granite / Granodiorite / Basalt / Cinders / Tuff / Rhyolite / Other Intrusive Igneous / Other Extrusive Igneous

**Adjacent Land Use:** Paved Road / Dirt Road / Trail / Railroad / Canals or Water Diversions / Grazing / Farming / Ranching / Stock Watering / Buildings / Fenceline / "Vacant Lot" / Other:

| Alphacode | Species Name | Prominence | Dispersion | Collection # |
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Prominence Codes: 5 = Dominant; 4 = Codominant; 3 = Associate; 2 = Uncommon; 1 = Rare

Dispersion Codes: 5 = growing in large almost pure population stands; 4 = growing in small colonies or forming larger carpets; 3 = forming large patches or cushions; 2 = forming clumps or dense groups; 1 = growing solitarily

# CPVAC VEGETATION RECORD

| Investigator | Date | Record No. | Relevé Number |
|---|---|---|---|
| | | | |

| Alphacode | Species Name | Prominence | Spacing | Collection # |
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| Layer | Height Code | | | Cover Code | Notes: |
|---|---|---|---|---|---|
| | Minimum | Maximum | Average | | |
| Dominant Tree | | | | | |
| Codom. Tree | | | | | |
| Dom. Shrub | | | | | |
| Codom. Shrub | | | | | |
| Forbs ❀ | | | | | |
| Graminoids ❀ | | | | | |
| Herbs ⊙ | | | | | |
| Moss | | | | | |
| Litter | | | | | |
| Bare | | | | | |

**❀ = Perennial Plants; ⊙= Annual Plants**

**Height Code: 6** = > 30 m; **5** = 8-30 m; **4** = 2-8 m; **3** = 1 - 2 m; **2** = 0.3 - 1 m; **1** = 0 - 0.3 m

**Cover Code: 5** = 75 - 100%; **4** = 50-75 %; **3** = 25-50%; **2** = 5-25; **1** = 1- 5%; **.1** = <1%; **0** = absent from plot

## CPVAC Releve Summary Table

| Location | Name |
|---|---|
| | |

| Species $\alpha$-Code | Releve Number | | | | | | | | | | | | | | | | Stats | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | Avg | Freq |
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## CPVAC Sorted Releve Summary Table

| Location | | | | | | Classification |
|---|---|---|---|---|---|---|
| Species α-Code | Species Name | Statistics | | | | Notes |
| | | Low | High | Mean | Freq % | |
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Formation:

Series:

Association:

Subassociation:

# CPVAC VEGETATION RECORD

| | | | | |
|---|---|---|---|---|
| Investigator: Rowlands | Date: 6/30/93 | Record No.: 7 | Relevé Number: 4 | |
| Land Ownership: USNPS | Administrative Unit: Mesa Verde N.P. | Administrative Sub-Unit: NA | State: CO | County: |
| Relevé: Pinyon-Juniper | Relevé Location: Near Resources Management Office | | | |
| Slope Percent or Degree: 3° | Aspect N / NE / E / SE / S / (SW) / W / NW / L | Elevation (m): 2,164 meters | Area (Ha): To Be Determined (TBD) | |
| Georeference Coord. (Lat./Long/UTM): TBD | | Zone (for UTM): | Airphoto I.D. and No.: None | |

| Photo No. North | Photo No. East | Photo No. South | Photo No. West | Remote Sensing Ref. DBF No.s | TM | Spot or Other |
|---|---|---|---|---|---|---|
| None | None | None | None | None | None | None |

| Soil Series | Soil Association | Soil Color | Dissection |
|---|---|---|---|
| TBD | TBD | TBD | None / (Low) / Med / High |

| % Boulder (>190mm) | % Cobble (65-190 mm) | % Gravel (3--64 mm) | % Sand (0.05-2mm) | % Silt (0.04-0.002 mm) | % Clay (<0.002 mm) | Soil Texture |
|---|---|---|---|---|---|---|
| Ø | Ø | 2% | 48% | 50% | | Gravelly Sandy Loam |

**Circle:** Rockpile / Bajada / Drainage Channel / Valley Bottom Fill / Side Slope / Lower Slope / Mid Slope / Upper Slope / Ridge / Floodplain / Interfluve / Slickrock / Terrace / (Mesa) / Butte / Cliff / Talus / Scree / Cinder

**Circle:** Alluvium / Conglomerate / (Sandstone) / Shale / Limestone / Dolomite / Serpentine / Marble / Schist / Gneiss / Granite / Granodiorite / Basalt / Cinders / Tuff / Rhyolite / Other Intrusive Igneous / Other Extrusive Igneous

**Adjacent Land Use:** (Paved Road) / Dirt Road / (Trail) / Railroad / Canals or Water Diversions / Grazing / Farming / Ranching / Stock Watering / (Buildings) / Fenceline / "Vacant Lot" / Other: Powerline Corridor

| Alphacode | Species Name | Prominence | Dispersion | Collection # |
|---|---|---|---|---|
| ASSC | Astragalus schmollii | 2 | | |
| POFE | Poa fendleriana | 3 | | |
| HEVI | Heterotheca villosa | 1 | | |
| PEPU | Petradoria pumila | 2 | | |
| AMUT | Amelanchier utahensis | 3 | | |
| PIED | Pinus edulis | 5 | | |
| PECR | Penstemon crandallii | 2 | | |
| LUCA | Lupinus caudatus | 2 | | |
| ERUM | Eriogonum umbellatum | 2 | | |
| YUBA | Yucca baccata | 2 | | |
| JUOS | Juniperus osteosperma | 3 | | |
| PECE | Pedicularis centrantha | 2 | | |
| MEOF | Melilotis officianalis | 1 | | |
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Prominence Codes: 5 = Dominant; 4 = Codominant; 3 = Associate; 2 = Uncommon; 1 = Rare

Dispersion Codes: 5 = growing in large almost pure population stands; 4 = growing in small colonies or forming larger carpets; 3 = forming large patches or cushions; 2 = forming clumps or dense groups; 1 = growing solitarily

# CPVAC VEGETATION RECORD

| Investigator | Date | Record No. | Relevé Number |
|---|---|---|---|
| | | | |

| Alphacode | Species Name | Prominence | Spacing | Collection # |
|---|---|---|---|---|
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| Layer | Height Code | | | Cover Code | Notes: |
|---|---|---|---|---|---|
| | Minimum | Maximum | Average | | |
| Dominant Tree PIED | 3 | 4 | 3.5 | 3 | |
| Codom. Tree JUOS | 1 | 4 | 2.5 | 2 | |
| Dom. Shrub AMUT | 2 | 3 | 2.5 | 2 | |
| Codom. Shrub None | NA | NA | NA | NA | |
| Forbs ❀ | 1 | 2 | 1.5 | 2 | |
| Graminoids ❀ | 1 | 1 | 1 | 2 | |
| Herbs ⊙ | 1 | 1 | 1 | 1 | |
| Moss | 1 | 1 | 1 | .1 | |
| Litter | NA | NA | NA | 2 | |
| Bare | NA | NA | NA | 2 | |

❀ = **Perennial Plants;** ⊙ **= Annual Plants**

**Height Code: 6** = > 30 m; **5** = 8-30 m; **4** = 2-8 m; **3** = 1 - 2 m; **2** = 0.3 - 1 m; **1** = 0 - 0.3 m

**Cover Code: 5** = 75 - 100%; **4** = 50-75 %; **3** = 25-50%; **2** = 5-25; **1** = 1- 5%; **.1** = <1%; **0** = absent from plot

## CPVAC Releve Summary Table

| Location | Name |
|---|---|
| Mesa Verde N.P. nr. R.M. Office | Rowlands |

| Species α-Code | Releve Number | | | | | | | | | | | | | | | | Stats | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | | | Avg | Freq |
| JUOS | 5 | 5 | 5 | 4 | 4 | 5 | | | | | | | | | | | 4.5 | 1.0 |
| PIED | 4 | 4 | 4 | 5 | 4 | 3 | | | | | | | | | | | 4 | 1.0 |
| POFE | 3 | 3 | 3 | 3 | 3 | 4 | | | | | | | | | | | 3.2 | 1.0 |
| LUCA | 3 | 3 | 3 | 2 | 4 | 4 | | | | | | | | | | | 3.2 | 1.0 |
| PECR | 3 | 3 | 2 | 2 | 3 | 3 | | | | | | | | | | | 2.7 | 1.0 |
| PUTR | 2 | 3 | 3 | 3 | 2 | 3 | | | | | | | | | | | 2.7 | 1.0 |
| YUBA | 2 | 2 | 2 | 2 | 2 | 3 | | | | | | | | | | | 2.2 | 1.0 |
| ASSC | 2 | 1 | 3 | 2 | 2 | — | | | | | | | | | | | 1.7 | .83 |
| SIHY | 2 | — | 3 | — | 2 | 3 | | | | | | | | | | | 1.7 | .67 |
| OPPO | 2 | 2 | 3 | — | 2 | — | | | | | | | | | | | 1.5 | .67 |
| HEVI | — | 2 | 3 | 1 | — | — | | | | | | | | | | | 1.3 | .67 |
| PHJU | 2 | 2 | — | — | — | — | | | | | | | | | | | 1.2 | .50 |
| MEOF | 2 | — | — | 3 | 2 | — | | | | | | | | | | | 1.2 | .50 |
| ERUM | 2 | — | — | 2 | 3 | — | | | | | | | | | | | 1.2 | .50 |
| ERIG SP. | — | 2 | 3 | — | — | 1 | | | | | | | | | | | 1 | .50 |
| AMUT | — | — | — | — | 2 | 3 | | | | | | | | | | | 0.8 | .33 |
| ERRA | — | 2 | — | — | — | 2 | | | | | | | | | | | 0.7 | .33 |
| CRWR | — | — | 3 | — | — | — | | | | | | | | | | | 0.5 | .17 |
| PEST | — | — | — | — | 2 | 1 | | | | | | | | | | | 0.5 | .33 |
| CAS SP. | — | — | — | — | 1 | 2 | | | | | | | | | | | 0.5 | .33 |
| PECE | — | — | — | 2 | — | 1 | | | | | | | | | | | 0.5 | .33 |
| ORHY | 1 | — | 2 | — | — | — | | | | | | | | | | | 0.5 | .33 |
| CHDO | — | — | — | — | — | 2 | | | | | | | | | | | 0.3 | .17 |
| POSA | 2 | — | — | — | — | — | | | | | | | | | | | 0.3 | .17 |
| KOCR | — | — | — | — | — | 2 | | | | | | | | | | | 0.3 | .17 |
| QUGA | — | — | — | — | — | 2 | | | | | | | | | | | 0.3 | .17 |
| CHDR | 2 | — | — | — | — | — | | | | | | | | | | | 0.3 | .17 |
| PEPU | — | — | — | 2 | — | — | | | | | | | | | | | 0.3 | .17 |
| ORPU | — | — | — | — | — | 2 | | | | | | | | | | | 0.3 | .17 |
| DEPI | — | — | — | — | 2 | — | | | | | | | | | | | 0.3 | .17 |

## CPVAC Sorted Releve Summary Table

| Location | Classification |
|---|---|
| Mesa Verde N.P. nr. R.M. Office | Pinus edulis - Juniperus osteosperma |

| Species α-Code | Species Name | Statistics Low | High | Mean | Freq % | Notes |
|---|---|---|---|---|---|---|
| JUOS | Juniperus osteosperma | 3 | 5 | 4. | 100 | |
| PIED | Pinus edulis | 3 | 5 | 4 | 100 | |
| POFE | Poa fendleriana | 3 | 4 | 3.2 | 100 | |
| LUCA | Lupinus caudatus | 2 | 4 | 3.2 | 100 | |
| PECR | Penstemon crandallii | 2 | 3 | 2.7 | 100 | |
| PUTR | Purshia tridentata | 2 | 3 | 2.7 | 100 | |
| YUBA | Yucca baccata | 2 | 3 | 2.2 | 100 | |
| ASSC | Astragalus schmollii | 1 | 3 | 1.7 | 83 | |
| SIHY | Sitanion hystrix | 2 | 3 | 1.7 | 67 | |
| OPPO | Opuntia polyacantha | 2 | 3 | 1.5 | 67 | |
| HEVI | Heterotheca villosa | 1 | 3 | 1.3 | 67 | |
| PHJU | Phoradendron juniper. | 2 | 3 | 1.2 | 50 | |
| MEOF | Melilotus officianalis | 2 | 3 | 1.2 | 50 | |
| ERUM | Eriogonum umbellatum | 2 | 3 | 1.2 | 50 | |
| ERIG.SP. | Erigeron sp. | 1 | 3 | 1.0 | 50 | |
| AMUT | Amelanchier utahenses | 2 | 3 | .83 | 33 | |
| ERRA | Erigeron racemosum | 2 | 2 | .67 | 33 | |
| CRWR | Cryptantha wrightii | 3 | 3 | .50 | 17 | |
| PEST | Penstemon strictis | 1 | 2 | .50 | 33 | |
| C.RS.SP. | Cirsium sp. | 1 | 2 | .50 | 33 | |
| PECA | Pedicularis centranthia | 1 | 2 | .50 | 33 | |
| ORHY | Oryzopsis hymenoides | 1 | 2 | .50 | 33 | |
| CHDO | Chaenactis douglasii | 2 | 2 | .33 | 17 | |
| POSA | Poa sandbergii | 2 | 2 | .33 | 17 | |
| KOCR | Koeleria cristata | 2 | 2 | .33 | 17 | |

Formation: Submontane Forest and Woodland

Series: Pinus edulis

Association: Pinus edulis - Juniperus osteosperma.

Subassociation: Ø