

**ECOLOGICAL ASSOCIATIONS OF PONDEROSA PINE INSIDE  
JEWEL CAVE NATIONAL MONUMENT, CUSTER, SOUTH DAKOTA**

**BY**

**DARREL L. MCDONALD**

**Department of Geography**

**Texas A&M University**

**College Station, TX 77843-3147**

*bibkey id: 548920*

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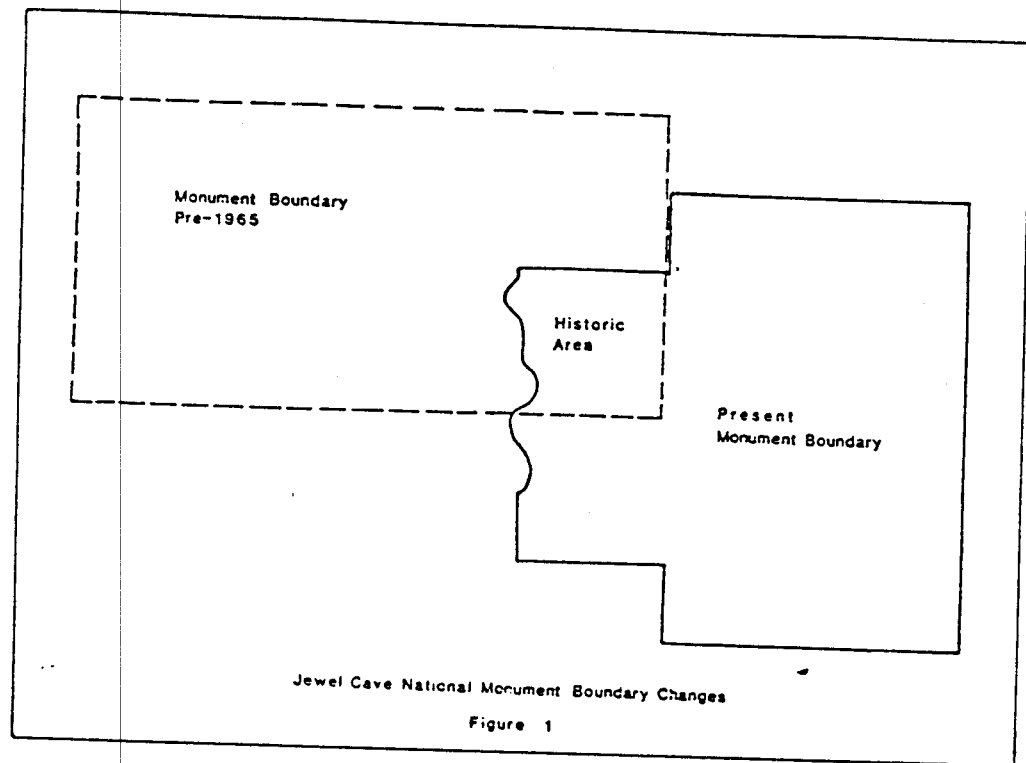
## ECOLOGICAL ASSOCIATIONS OF PONDEROSA PINE INSIDE JEWEL CAVE NATIONAL MONUMENT, CUSTER, SOUTH DAKOTA

The objectives of this report are to determine the ecological relationships between forest habitats and the influence of soils and topography upon the distribution of forest habitats of Jewel Cave National Monument (JECA), Custer, South Dakota. The dominant forest species is ponderosa pine (*Pinus ponderosa* var. *scopulorum*). Within JECA's boundaries, natural and managed stands of different forest habitats can be delineated into three broad canopy cover classes (habitats) on aerial photos; 1) closed canopy (crowns touching), 2) open canopy (crowns not touching) and 3) parklands (grasses dominant). Soils vary inside JECA (Custer County Soil Survey 1983).

Mapping forest cover types as a surrogate for forest habitats and comparing the resulting patterns to soils distributions, may reveal useful information about influence of soils upon the distribution of forest cover types in JECA. In addition, examination of data depicting the ecological nature of ponderosa pine habitats will provide information about the most significant influences upon pine forest habitats.

JECA is located thirteen miles west of Custer, South Dakota. Although the date of discovery is not certain, the cave was claimed in 1900 as the "Jewel Tunnel Lode" by Frank and Albert Michaud and their business partner Charles Bush. The name was derived from a layer of calcite crystals lining the cave walls (Michaud 1970). The cave as mapped by the Michauds, was approximately one mile in length. Further exploration and mapping (most notably by Herb and Jan Conn and Mike Wiles) have extended the mapped length of the cave to over seventy-two mile (Wiles personal communication 1984). With this added mileage Jewel Cave became the second longest cave in the United States and fourth longest cave system in the world (Conn 1977).

forest tract in the historic area a unique location in which to study the ecological implications of differing management policies upon ponderosa pine habitats.



Patterns of forest cover and surface conditions can provide information about the effects of different management schemes on forest dynamics. Investigations of forest habitats and relationship to soils will provide basic geographic information for JECA. This type of comprehensive data is not presently available (Ditmanson 1983).

### PHYSICAL GEOGRAPHY

JECA lies on the southwestern flank of the Black Hills Dome. This dome is largely comprised of a central mountainous core of complex Precambrian granitic and metamorphic rocks surrounded by plateaus and ridges of sedimentary strata (mainly limestones and sandstones). JECA is located on the edge of the Pahasapa Limestone which is Mississippian in age (Figure 2). The cave is believed to have

the Rockerville series generally occupies canyons. Both of these soil series are thin (Custer County Soil Survey 1983).

## METHODS

Data to examine the ecological associations of JECA ponderosa pine forest communities were collected using quadrat sampling techniques. Nine plots that measured 30 m x 30 m were laid out in the historic area to represent an equal sampling of the three canopy cover classes; closed canopy, open canopy, and parkland. The selection of sample plots was a stratified random design. These plots were selected in a manner to produce two cross-sections of varying slope, location and aspect occupied by forest communities inside JECA.

The total number of trees in each plot was recorded. A representative sample of pines were used to generate data for description of ecological characters for each plot. Seventeen variables were recorded for each tree in the analysis of habitats (See definitions in Appendix A). The principal individual pine characteristics measured included: 1) tree height which was determined by triangulation; 2) diameter of tree measured by a steel tape; 3) canopy level determined by the observer; and 4) branch geometry of the pine, which was calculated as an arc distance based upon a full circle.

Characteristics of the ground surface were also studied by taking measurements of the nature and depth of litter beneath the crown radius. The presence, absence, number and species of seedlings found within two meters of the sampled pine and type of understory vegetation present were all recorded.

A final set of characteristics dealing with aspect and stability of sample plots was recorded. Among this set were the following: 1) aspect obtained from compass directions; 2) slope condition in relation to erosional processes; 3) the location of the sample plot in regard to topography; 4) the steepness of slope; and 5) the angular measurement of exposure to sunlight during a summer day. The final data set

(*Andropogon* spp.) and needle and thread (*Stipa comata*). The density of grasses was greater where more light reached the forest floor. The most common shrubs found in JECA were juniper (*Juniperus communis*) and mountain mahogany (*Cercocarpus montanus*).

#### CLOSED CANOPY

Closed canopy pine forest was generally located on north-facing slopes. The height of the upper canopy ranged from 45-65 feet. Closed canopy forest habitat was often located on steep slopes (40 to 55%). Although dense forest canopies are not the most productive, dense cover on steep slopes reduce erosion as well as deter overuse by visitors.

The understory of the closed pine forest was usually quite sparse with only scattered clumps of grass and some flowering plants surviving on limited available diffuse sunlight.

The litter of the closed canopy habitat was mainly composed of pine needles and duff (2-4 inches in thickness), scattered decaying trunks and branches. The mat of needles influences the density of the understory by modifying the local microenvironment. Tannins produced by needle decay inhibit vegetation growth because of its acidic nature (Archer personal communication 1985). Occasionally, *dog hair* stands of pines (dense-stunted pines) were observed in closed canopy habitats. The litter under these densely-spaced pines was greater than in other forest habitats (up to 5-6 inches).

#### OPEN CANOPY

Open canopy habitats were most often located on south-facing slopes. Spacing of pines was such that crowns did not touch, allowing more sunlight to reach the forest floor. In response to this added energy the understory of open canopy forest habitats was more varied and dense than closed canopy habitats. Understory grasses

biomass. Invasion of pine seedlings and saplings around the periphery of parklands was common.

## SOILS

There are five major soil associations recognized inside JECA (Custer County Soil Survey 1983). The following are descriptions of the general characters of these associations.

### SAWDUST-ROCKERVILLE ASSOCIATION (10 TO 40 % slopes)

These soils overlie deep to fractured bedrock. This association is derived from sedimentary rocks on the lower Limestone Plateau. Permeability is moderate in this association; runoff is medium to rapid.

Sawdust soils occur on south-facing slopes. Typically, the surface layer is a dark grayish-brown calcareous channery loam about 4 inches thick. Subsoils may be quite deep (up to 60 inches); water holding capacity is low.

Rockerville soils generally occur on north-facing slopes. The surface layer is a brown channery loam about 2 inches thick. Subsoils tend to be thinner (20 to 40 inches) than in Sawdust soils.

### ROCK OUTCROP-SAWDUST COMPLEX (40 TO 80 % slopes)

This complex is typified by rock outcrops and deep well-drained soils on uplands. It is derived from local sedimentary materials (limestones and sandstones). Rock outcrops make up the majority of this association (45 to 55%). This complex is found on all parts of the landscape on north-facing slopes. Permeability is moderate in the Sawdust. Runoff is rapid to very rapid on this complex; available water capacity is low. Rock outcrops are hard fractured limestone forming nearly vertical ledges. The Sawdust soil complex has been described above.

## ANALYSIS AND DISCUSSION

The objectives of this report were to determine the relationships between forest habitats and soil associations and to identify significant ecological characteristics of the three delineated pine forest habitats. Comparisons of forest cover type patterns and soils distributions yielded useful information, which is discussed below.

In general, closed canopy forest habitats in JECA were located on north-facing slopes. In most locations, Rockerville soils were dominant. On south-facing slopes, Sawdust soils were generally found under open forest habitats. Parklands, particularly naturally occurring parklands, tended to be located in canyon bottoms or on south-facing slopes in association with Bull Flat-Cordeston silt loams and Sawdust soils. Other occurrences of parkland habitats coincided with developed areas.

The distribution of the five major soil associations was uneven. There were three main and two minor soil associations on JECA. The Sawdust-Rockerville Complex occupied 703 acres (54.9% of total). The Rock Outcrop-Sawdust Complex was located on 296 acres (23.1%); and the Rockerville-Sawdust-Rock Outcrop Soils contributed 218 acres (17%) to the total acreage. Although the Bull Flat-Cordeston silt loams were found on only 16.7 acres (1.3%), these soils are significant because of their high organic content. The Rockerville-Paunsaugunt Complex occupied 44.3 acres (3.4%) on well-drained to excessively well-drained upland sites.

The distribution of forest canopy cover types, delineating forest habitats, was also unequal. Open canopy forest habitats were most common. This canopy cover type was found on 714 acres (55.8%) of JECA's 1280 acres. Closed canopy forest habitats occupied 403 acres (31.5%); whereas parklands were located on 161 acres (12.5%).

The first ecological character examined was tree diameter. Because of the strong correlation between tree diameter and height two regression models were run; first, height was included as an independent variable, then height was excluded as an independent variable. The following three models produced the highest coefficients of determination in each of the forest habitats delineated with height as an included independent variable:

| <u>R<sup>2</sup></u> | <u>HABITAT</u> | <u>REGRESSION EQUATION</u>                 |
|----------------------|----------------|--------------------------------------------|
| 0.86                 | CLOSED         | DBHS = 5.89 + .02 HGTS + 1.32 S + 1.59 AP  |
| 0.86                 | OPEN           | DBHS = 5.79 + .02 HGTS - .69 A + 1.50 S    |
| 0.97                 | PARKLAND       | DBHS = .07 + .02 HGTS + .09 BGE - .23 SLC. |

In each of the habitats HGTS (height) was the most important factor, as expected from the results of the correlation table. The variables S (steepness of slope), SLC (slope condition), A (aspect) and AP (trees in understory were only pine) added small but significant power to their respective models.

Next, multiple regression models were run for each habitat excluding the independent variable height. The results of these linear regressions differed from the previous set of models. The best models produced were:

| <u>R<sup>2</sup></u> | <u>HABITAT</u> | <u>REGRESSION EQUATION</u>                  |
|----------------------|----------------|---------------------------------------------|
| 0.64                 | CLOSED         | DBHS = -22.20 + 1.59 A + 10.43 S - .12 CDEN |
| 0.71                 | OPEN           | DBHS = 2.40 + 2.02 SE - .82 A - .18 CDEN    |
| 0.85                 | PARKLAND       | DBHS = 3.79 + 1.28 SE - .81 US - .09 CDEN.  |

In this set of regressions equations CDEN (sampling percentage) from each plot was most significant. This class variable reflected the relative presence of a general tree size sampled compared to all trees in the plot. Again the variable aspect added limited significance to the model. It was interesting to note when a set of

A point to note from this set of regressions was that SE (sun exposure) added significant power to all models. The next step of data analysis was to test variables that effected sun exposure. The results produced from models testing sun exposure were varied. Limited explanatory power was gained from the model for closed forest habitats but open forest habitat and parkland models yielded some insight:

| <u>R<sup>2</sup></u> | <u>HABITAT</u> | <u>REGRESSION EQUATION</u>               |
|----------------------|----------------|------------------------------------------|
| 0.41                 | CLOSED         | SE = 2.03 + .34 CAN + .53 BGE + .86 AP   |
| 0.82                 | OPEN           | SE = .79 + 1.19 CAN + .18 BGE + .60 AP   |
| 0.85                 | PARKLAND       | SE = 2.39 + .01 HGTS + .34 BGE + .29 US. |

From these models branch geometry and canopy level were important variables with respect to sun exposure.

The Natural and Cultural Resource Plan for JECA expressed concern that litter in the understory of forest habitats represents hazardous fuels that are a potential fire problem. Therefore, models were tested to examine ecological characteristics that influenced litter production in each delineated habitat.

Results of these models varied. Variation was accounted for better in open forest habitats and parklands than for closed forest habitats:

| <u>R<sup>2</sup></u> | <u>HABITAT</u> | <u>REGRESSION EQUATION</u>           |
|----------------------|----------------|--------------------------------------|
| 0.44                 | CLOSED         | L = 1.31 + .09 DBHS + .27 A + .07 DE |
| 0.83                 | OPEN           | L = -.25 - .37 A + 1.39 S + .67 R    |
| 0.83                 | PARKLAND       | L = 8.88 - 1.80 A - .83 S + .29 R.   |

The models for litter production in open canopy and parkland habitats show promise as these variables can be remotely sensed.

The presence of R (bedrock exposure) in two of the models generated the testing of variable effects on bedrock exposure in the sample plots. This set of linear

## SUMMARY AND CONCLUSIONS

The results of this report suggested data analyzed do not clearly answer important questions about the distinctiveness of pine forest habitats and interactions of ecological characteristics in each habitat.

The geographic information generated from examination of the constructed overlays revealed no causal relationships between forest habitat distribution and soil associations. This may be a function of the fact most soils found on the Monument, particularly upslope soils, were derived from similar parent material. Three main soil associations comprised 1216 acres of surface area on the Monument. Although limited, the minor soils of the Monument were significant; especially the Bull Flat-Cordeston silt loam complex. This organically rich alluvium, found in canyon bottoms, supported a more varied flora than hillslopes. At times rare flowering plants have been observed in this habitat. This is important because it added to the diversity of the plant communities found on the Monument. The Rockerville-Paunsaugunt Complex proved interesting because it was found only on the highest parts of the landscape.

Additional geographic information compiled by this report indicated open forest habitats occupied over one half of the Monument's surface area; generally on south-facing slopes. Sawdust soils were located under this habitat. Expansion of this habitat was influenced by applied management techniques. The majority of closed forest habitats were found to occupy north-facing slopes supported by Rockerville soils. Natural parklands occupied canyon bottoms and occasionally south-facing slopes. Parklands on other areas of the Monument reflected cultural features built to facilitate visitation.

Generally, linear regression models generated from field data accounted for more variation in parkland habitats. Models produced for open forest habitats accounted for a sizable amount of the variance using characteristics tested; poorest

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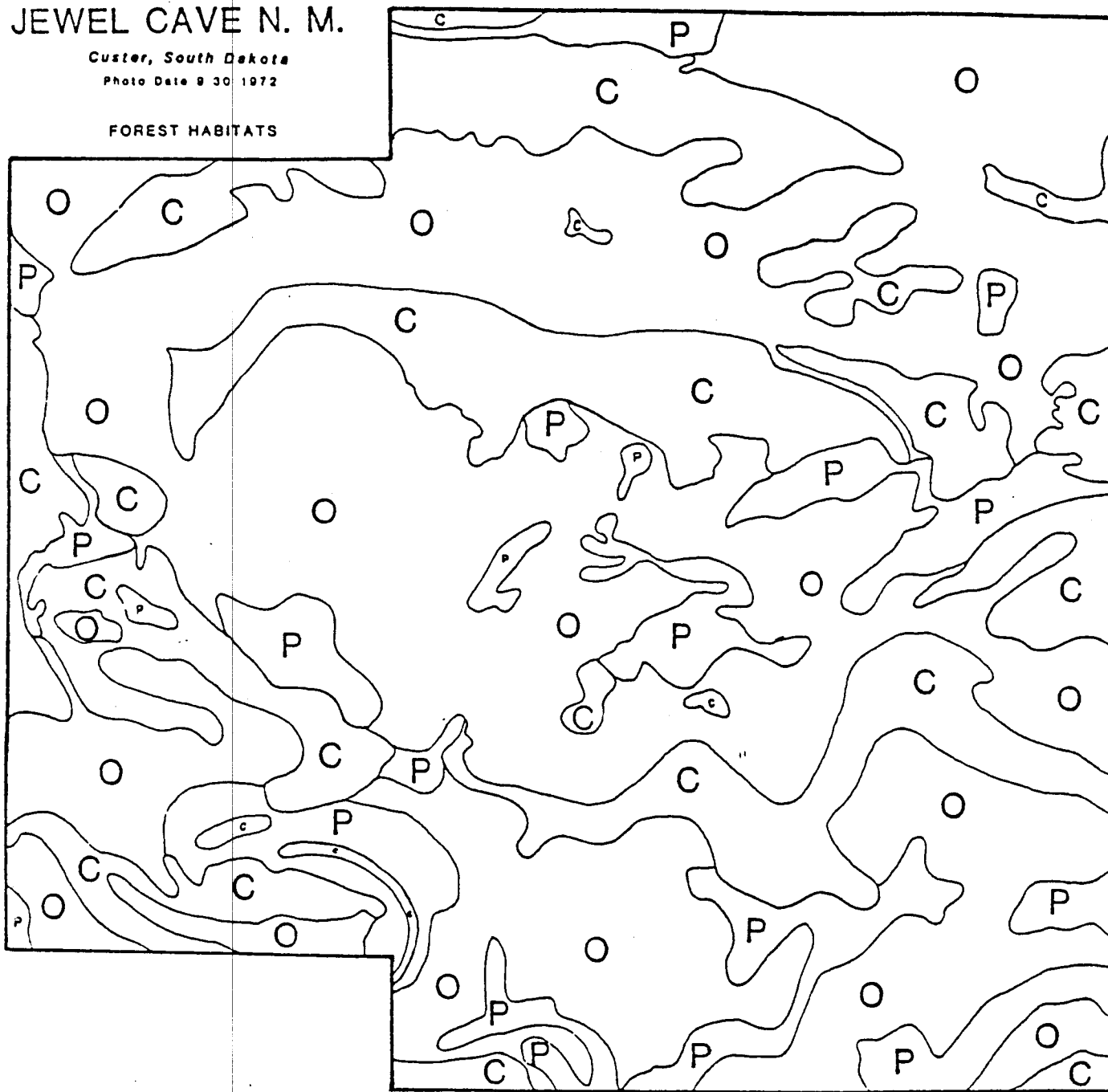
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# JEWEL CAVE N. M.

Custer, South Dakota

Photo Date 9 30 1972

## FOREST HABITATS



### Legend

- C Closed Forest
- O Open Forest
- P Parkland



Scale 1:7700

0 .1 mi.

## VARIABLE DEFINITIONS

- A (ASPECT) - This variable numerically recorded the compass direction faced by sample trees.
- AP (ALL PINE) - A binary variable which indicated whether or not all trees within 2 meters of sample tree were pines.
- BGE (BRANCH GEOMETRY) - This class variable indicated an angular measure of pine branches based on a full circle.
- CAN (CANOPY LEVEL) - A class variable which described the position of sample trees with respect to highest tree crown.
- CDEN (CENTRAL DENSITY) - This variable was a percentage that represented the relative presence of a tree class size with respect to all tree class sizes sampled.
- D (DEBRIS) - This class variable recorded the type of debris found beneath crown of sampled pine.
- DBHS (TREE DIAMETER) - Tree diameters were measured at breast height.
- DE (DENSITY) - This variable indicated the number of trees within two meters of sampled tree.
- HGTS (TREE HEIGHT) - Tree heights were determined by triangulation.
- L (LITTER) - This variable represented a measurement of litter depth from surface down to mineral soil.
- P (PLOT NUMBER) - This variable recorded the plot number.
- S (SLOPE STEEPNESS) - This variable was the measured angle of sample plot in degrees.
- SC (SAME CANOPY) - This binary variable indicated whether or not all trees within 2 meters were in the same canopy level.
- SE (SUN EXPOSURE) - This class variable represented an angular measurement of the time a tree would receive sunlight.
- SLC (SLOPE CONDITION) - This class variable indicated the amount of erosional activity found beneath sample pines.
- SLL (SLOPE LOCATION) - Class variable that described the position of sample plots (ranged from hilltop to canyon bottom).
- US (UNDERSTORY) - This class variable described the type of plant communities found beneath sampled trees.

Darrel McDonald  
08/08/84

Not in herbarium or needed specimens collected this year

1. Musineon tenusifolium Nutt. ex. T. & G. #179
2. Musineon divaracatum (Pursh) Nutt. ex. T. & G. #199
3. Dodecatheon pulchellum (Raf.) Merrill #187
4. Antennaria neglecta Greene #186
5. Mertensia lanceolata (Pursh) DC. ex. A.DC. #182
6. Asclepias ovalifolia Decne. #210
7. Delphinium nuttallianum Pritz. ex. Walpers #184
8. Spaeralcea coccinea (Nutt.) Rydb. #193
9. Anemone multifidia Poir. #197
10. Trifolium hybridum L. #200
11. Physocarpus monogynus (Torrey) Coult. #201
12. Ranunculus rhomboides Goldie(?) #202
13. Erysinum apserum (Nutt.) DC. #204
14. Lathyrus polymorphus Nutt. #211
15. Galium boreale L. #214
16. Rosa sayi Schwein. #221
17. Cirsium canascens Nutt. #216

|     |                                             |   |
|-----|---------------------------------------------|---|
| 26. | <u>Hymenoxys acaulis</u> (Pursh) Parker     | 6 |
| 27. | <u>Anemone pateus</u> L.                    | 3 |
| 28. | <u>Gaura coccinea</u> Nutt ex. Pursh        | 4 |
| 29. | <u>Allium textile</u> Nels. & Macbr.        | 4 |
| 30. | <u>Achillea millefolium</u> L.              | 2 |
| 31. | <u>Lesquerella arenosa</u> (Richards) Rydb. | 4 |
| 32. | <u>Antennaria rosea</u>                     | 6 |
| 33. | <u>Prunus virginiana</u> L.                 | 1 |
| 34. | <u>Cynoglossum officinale</u> L.            | 2 |
| 35. | <u>Sisyrinchium montanum</u> Greene         | 4 |
| 36. | <u>Ribes cereum</u> Dougl.                  | 2 |
| 37. | <u>Fragaria virginiana</u> Duchesne         | 3 |
| 38. | <u>Viola adunca</u> Smith                   | 3 |
| 39. | <u>Viola canadensis</u> L.                  | 4 |
| 40. | <u>Iris missouriensis</u> Nutt.             | 2 |
| 41. | <u>Aquilegia brevistyla</u> Hook.           | 2 |

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