

A STUDY OF PLANT SUCCESSION ON
THE GOTHIC EARTHFLOW

by

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Introduction:

The presence of certain topographic, stratigraphic and structural features combined with excessive amounts of soil water resulted in an extensive earthflow near Gothic, Colorado, the present site of Rocky Mountain Biological Laboratory. Information from tree ring analysis, local observations and climatic data established the date of occurrence as 1923 (Langenheim, 1949).

Previous work done by Dr. Jean H. Langenheim described the physiography, environmental conditions and plant communities of the earthflow. Ten one meter by one meter permanent quadrats were established on the earthflow for studying changes in species populations and possible successional relationships during the years 1947-1954, with the exception of 1953 (Langenheim, 1956). In the present study, the quadrats were relocated and their vegetative composition was analyzed as had previously been done. This study was undertaken to elucidate successional patterns in the revegetation of the earthflow.

Earthflow occurred in the East River Valley, approximately 10 miles south of Gothic. It is located in Sec. 11, T. 13 S., R. 4 E., Gunnison County, Colorado. The Gothic Earthflow is nearly one mile long from the upper scarp (elevation 9,950 feet) to the valley floor (elevation 9,200 feet) and one quarter mile wide. The surface of the earthflow is exposed towards the southwest (Langenheim, 1956).

The Gothic Earthflow resulted from the combined effects of flowage and slippage. Langenheim divided it into six areas based on physiographic differences (Fig. 1). Area I is the upper break away scarp, a region of glacial moraine overlying indurated shale exposed by the downward movement of the slump block. Area II is the slump block consisting of a comparatively unaltered fescue grassland. Both flowage and slippage have occurred in Area III, the lower break away scarp. The eastern portion is characterized by unstable shale particles on a steeply sloping surface. The western portion is composed of islands of vegetation that have slipped down a relatively stable slope. The main body of the earthflow is included in Area IV, the largest disturbed region. This gently sloping area is covered by shale fragments in differing degrees of degradation. Large blocks of indurated shale as well as boulders from the glacial moraine are particularly evident in some parts of Area IV (Figs. 2 & 3). Area V is the slope descending to the valley floor. Tongues of debris cut by drainage channels alternate with undisturbed areas. Area VI is the valley floor consisting of the flood plain of the East River



Figure 2
Area IV as seen from Area III.
Note blocks of indurated shale
and morainal boulders.

Figure 3
Blocks of indurated shale in
the eastern portion of Area IV.



ith shale fragments.

Materials and Methods:

In 1947, the ten permanent quadrats were randomly located on the surface of the earthflow and its associated slump block. Two quadrats were placed in the Festuca meadow for sampling the vegetation that had characterized this part of the East River Valley before the occurrence of the earthflow in 1923. The other eight quadrats were situated on the bare parts of Areas IV and V; quadrats I-IV in a Chaenactis alpina community and quadrats V-VIII in a perennial forb community. Each quadrat was carefully located with reference to one of the four survey stations. Wooden stakes, reference stones and cairns were used to mark the corners of the quadrats. Density and frequency data was gathered from each quadrat (Langenheim, 1949).

The quadrats were relocated primarily by the use of a topographic map Dr. Langenheim had made with a plane table and alidade (Fig. 1). Measurements were made and compass readings were taken from structural features and the survey stations indicated on the map. The directions and distances were then measured off from these points in the field. However, difficulties were encountered in finding some of the quadrats. During the fifteen year interval in which the quadrats were not recharted, many of the quadrat markers were obliterated. Only in one quadrat (quadrat II) were all four wooden stakes, the reference stones and cairn present. In the other quadrats, the presence of the corner markers was much less evident. The quadrats located in the fescue grassland were the hardest to relocate. Perhaps this can be attributed to the cattle grazing

acted as strong agents in the destruction of the
also, the abundance of vegetation and morainal deposits
able of obscuring the presence of an area marked off with
ages and stones.

The quadrats were remarked by placing wooden stakes approximately 12"-18" in height in each corner (Figs. 4-13). In some cases such as in the grassland quadrats, the corners had to be approximated since there was little if any evidence of previous markers. The boundaries of the meter square quadrats were further marked off by string placed around the stakes (Fig. 12).

Plants appearing in the quadrats were collected and identified using H.D. Harrington's Manual of the Plants of Colorado. Densities (numbers of individuals of a species per quadrat) and frequencies (percentages of total number of quadrats in which a species occurs) were computed from data compiled from each quadrat. All counted plants were alive. In addition, all plants within a ten to fifteen foot radius of the quadrats were listed.

Many factors were considered in making plant counts to calculate the densities. Plants of the same species were in different stages of maturity. The problem of what constituted an individual plant arose several times, particularly with many of the grasses such as Festuca thurberi which grows in bunches and the perennial forb, Eriogonum umbellatum, which grows in mats. Difficulties lie in determining the extent of an individual from the aerial portion of the plant. From density and frequency figures, no idea of the pattern of distribution of individual species within a quadrat, their height or the spatial relation of their branching foliage can be obtained.



Figure 4

Quadrat I-located below the flow part of Area III with a substratum consisting of stabilized shale particles ranging from 1-10 mm. in length (fragments becoming increasingly finer with depth). A few larger particles as well as morainal rocks are found on the surface. The area is not heavily vegetated.

Figure 5

Quadrat II-located NW of a grove of aspen trees and E of blocks of indurated shale in Area IV. Surface shale is like that in Quadrat I, but a finer, brownish soil exists below. More vegetation is present around this quadrat.

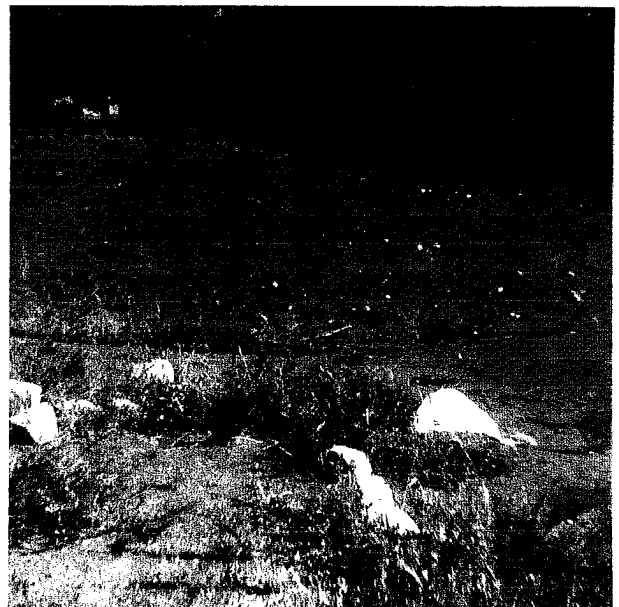




Figure 6
Quadrat III-located below the flow part of Area III, not far NW of Quadrat I with a similar substratum. An Artemisia tridentata community practically surrounds the quadrat which itself is hardly vegetated.

Figure 7
Quadrat IV-located on one side of a drainage channel in Area V. The shale fragments ranging in size from 2-4 mm. long (with larger ones on the surface) are less stable because of the slope. Small riverlets run through the area.

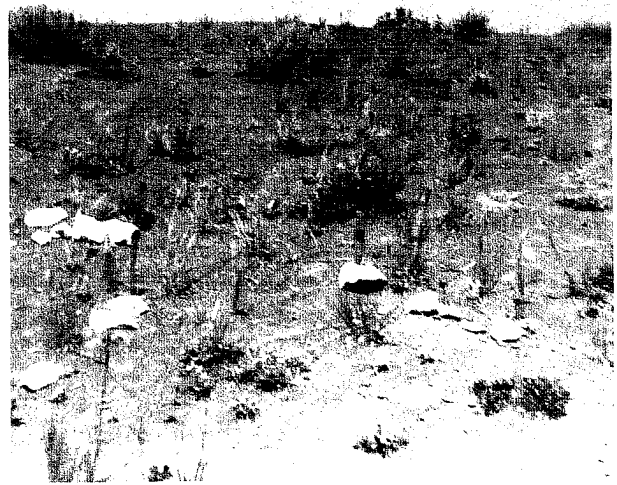


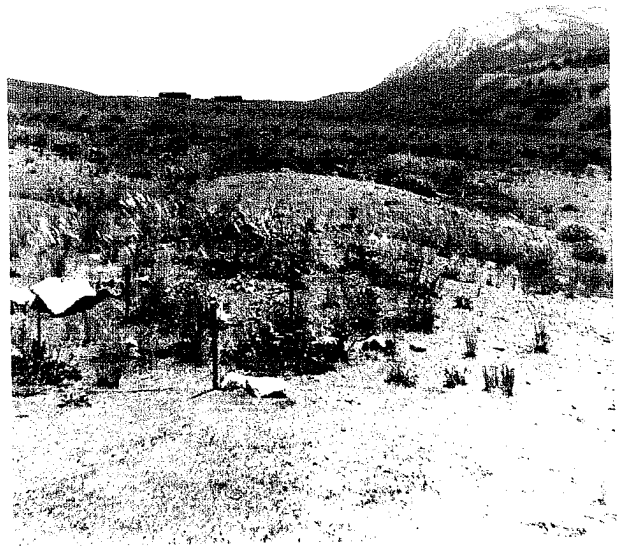


Figure 8

Quadrat V-located in Area IV where blocks of indurated shale are prominent features. Thin shale plated from 8 cm. long to smaller and rocks are scattered over the surface with smaller, more degraded particles below. The plants within this quadrat consisted almost entirely of seedlings.

Figure 9

Quadrat IV-located in a gently sloping region of stabilized shale fragments ranging from 3-10 mm. in length to finer brownish-gray soil beneath. This region is not heavily vegetated, but an Artemisia tridentata community lies to the SE.



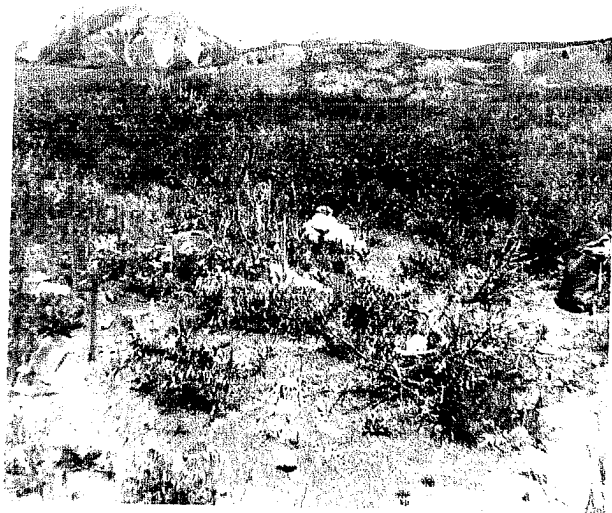


Figure 10
 Quadrat VII-located in a gently sloping region of Area IV with willows and other shrubs to the S and Artemisia tridentata to the W. The stabilized shale particles have brownish soil beneath them. The presence of much vegetation especially Rosa woodsii is noticeable.

Figure 11
 Quadrat VIII-located in the center of a slump region in Area IV. The substratum consists of finer shale particles ranging from 2-4 mm. in length. The area is heavily vegetated especially with stands of Rosa woodsii.



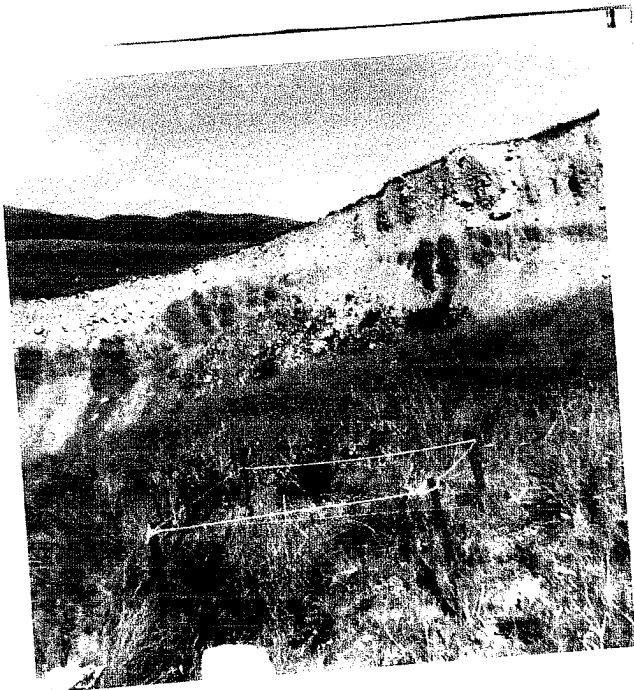


Figure 12
 Quadrat IX-located in the middle of
 a Festuca meadow in an area elevated
 by differential faulting of the slump
 block. Large boulders from glacial
 moraine abound. A good soil profile
 has developed, but the soil is ven-
 eered with rocks and rock particles.

Figure 13
 Quadrat X-located in the Festuca
 meadow of Area II near the top of
 the slump region in Area III.
 Rocks from morainal debris approx.
 5 cm. in length or smaller are
 scattered over the well developed
 soil. Artemisia tridentata are
 found NE of the quadrat and large
 mats of Eriogonum umbellatum are
 abundant.



Considerations are very important in vegetative sampling and, therefore, of ecological significance. However, to simplify matters, juvenile and mature plants were treated equally and amounts of coverage were not measured in this study.

Results:

The following tables list the densities of species found in the quadrats during the years studied (1947-1954 data taken from Langenheim, 1956). A list of the plants appearing within a ten to fifteen foot radius from the quadrat boundaries (not including those found within the quadrat) is also included. Those plants outside the quadrat that once were recorded as being within the quadrat are starred.

QUADRAT I

Species	1947	1948	1949	1950	1951	1952	1954	1969
- Chaenactis alpina	27	6	13	30	10	8	4	1
- Taraxacum officinale			1	1		1	1	1
- Hackelia floribunda						1		3
-+Sitanion hystrix							2	5
- +Bromus polyanthus								1
++Eriogonum umbellatum								1
- Chrysothamnus parryi								2
Aster bigelovii								1

Species found in the vicinity of the quadrat:

Chrysopsis villosa
 Agropyron trachycaulum
 Artemisia tridentata
 Poa pratensis
 Potentilla gracilis
 Chenopodium sp.
 Linum lewisii

+ each clump counted as an individual plant

++ each mat counted as an individual plant

QUADRAT II

Species	1947	1948	1949	1950	1951	1952	1954	1969
<i>Chaenactis alpina</i>	66	28	12	16	3			
<i>Eraxacum officinale</i>			2	8	6	4	2	17
<i>Hackelia floribunda</i>			2		2	6		
<i>Gayophytum nuttallii</i>					6	5		
<i>Chenopodium fremontii</i>						2		
<i>Moldavica parviflora</i>							2	
<i>Eriogonum umbellatum</i>								5
<i>Chrysothamnus parryi</i>								10
<i>Aster bigelovii</i>								2
+ <i>Carex</i> sp.								42
+ <i>Artemisia dracunculus</i>								2
<i>Viola nuttallii</i>								1

Species found in the vicinity of the quadrat:

Agropyron trachycaulum
Stipa columbiana
S. columbiana nelsoni
Poa pratensis
 **Hackelia floribunda*
 **Chaenactis alpina*
Penstemon strictus
Gilia aggregata
Linum lewisii
 **Moldavica parviflora*
Eriogonum pauciflorum
Artemisia tridentata
Phacelia heterophylla
Potentilla gracilis
Chrysopsis villosa
Agoseris glauca
 **Gayophytum nuttallii*
 **Chenopodium* sp.
Bromus porteri Coult.
Polygonum douglasii
Senecio serra
Descurainia richardsonii
Thymus sp.
Phleum sp.

QUADRAT III

Species	1947	1948	1949	1950	1951	1952	1954	1969
<i>Chaenactis alpina</i>	82	42	4	24	14	16	9	
<i>Taraxacum officinale</i>	8	2			8	12	6	
<i>Carex siccata</i>			3				4	
<i>Hackelia floribunda</i>				2	8	14	1	
<i>Gayophytum nuttallii</i>					20	15	8	
<i>Polygonum aviculare</i>				4			4	
<i>Linum lewisii</i>							2	
<i>Phacelia leucophylla</i>							2	
<i>Chrysothamnus</i> sp.							4	
Grass (undet.)							2	
<i>Penstemon strictus</i>							2	
<i>Sitanion hystrix</i>								2
<i>Bromus polyanthus</i>								1
<i>Eriogonum umbellatum</i>								1
<i>Artemisia tridentata</i>								1
<i>Moldavica parviflora</i>								1

Species found in the vicinity of the quadrat:

**Chrysothamnus parryi*
Aster bigelovii
 **Linum lewisii*
Poa pratensis
Potentilla gracilis
 **Taraxacum officinale*
Achillea millefolium
 **Chaenactis alpina*
Chrysopsis villosa
Gilia aggregata
Senecio serra
 **Phacelia heterophylla*

QUADRAT IV

Species	1947	1948	1949	1950	1951	1952	1954	1969
Chaenactis alpina	115	42	30	46	26	4	7	1
Taraxacum officinale		1				1		
Penstemon strictus					2			5
Bromus inermis					2	3	6	
B. polyanthus								6
Chenopodium fremontii						1		
Grass (undet.)						1	1	
Chrysothamnus parryi							2	
Sitanion hystrix								2
Eriogonum umbellatum								2
E. pauciflorum								2

Species found in the vicinity of the quadrat:

*Chrysothamnus parryi
 Lupinus sp.
 Agropyron trachycaulum
 Stipa columbiana
 *~~Chaenactis alpina~~
 Hackelia floribunda
 Artemisia tridentata
 Phacelia heterophylla

QUADRAT V

Species	1947	1948	1949	1950	1951	1952	1954	1969
Chaenactis alpina	24	6	1		1	4	1	5
Taraxacum officinale	4	6	5	8	8	6	6	5
Sitanion hystrix	2	10	11	24	7	18		6
Gilia aggregata	2		3	1	5	2	1	4
Aster bigelovii			1	1	1	2		
Agropyron trachycaulum				3	5	2		2
Polygonum aviculare					2			
Grass (undet.)								
Carex siccata							7	3
Carex sp.							9	
Bromus polyanthus								12
Eriogonum umbellatum								3
Penstemon strictus								3
Chrysothamnus parryi								2
Phacelia heterophylla								2
Chrysopsis villosa								1
								1

Species found in the vicinity of the quadrat (V):

Artemisia tridentata
 A. dracunculus
 Hackelia floribunda
 *Aster bigelovii
 Achillea millefolium
 Linum lewisii
 Fragaria sp.
 Symphoricarpos sp.
 Phleum pratense

QUADRAT VI

Species	1947	1948	1949	1950	1951	1952	1954	1969
Chaenactis alpina	38	1	2		4	1	1	
Taraxacum officinale	5	4	4	4	3		1	16
Sitanion hystrix	1	2	2	8	2	12	3	12
Agropyron trachycaulum	2	3	3	5	6	1		2
Penstemon strictus	2	6	7	12	6	14	10	3
Artemisia tridentata			1		1	1	1	1
Polygonum aviculare					40	6	2	
Stipa columbiana					1	4	4	
Capsella bursa-pastoris						2		
Grass (undet.)								
Hackelia floribunda							5	7
Bromus polyanthus								1
Eriogonum umbellatum								2
Chrysothamnus parryi								6
								1

Species found in the vicinity of the quadrat:

*Chaenactis alpina
 Chrysopsis villosa
 Gilia aggregata
 Phacelia heterophylla
 Aster bigelovii
 Lupinus sp.
 Poa interior
 *Stipa columbiana

QUADRAT VII

Species	1947	1948	1949	1950	1951	1952	1954	1969
<i>Penactis alpina</i>	38	19	20	28	6	1		1
<i>Paraxacum officinale</i>		3	8	8	10	5	5	20
<i>Artemisia dracunculus</i>	21	20		22	4		9	1
<i>A. tridentata</i>			1		1	2	3	3
<i>Erigeron speciosus</i>	4	3						
<i>Agoseris glauca</i>			1					
<i>Aster bigelovii</i>			2		4			
<i>Eriogonum coloradense</i>			1	1	1	1	6	
<i>E. pauciflorum</i>								1
<i>E. umbellatum</i>								9
Grass (undet.)			2				1	1
<i>Agropyron trachycaulum</i>			1					
<i>Gilia aggregata</i>					1			3
<i>Sitanion hystrix</i>					2		3	2
<i>Penstemon strictus</i>					1		3	
<i>Bromus polyanthus</i>						1		2
<i>Hackelia floribunda</i>							1	
<i>Castilleja linariaefolia</i>								1
<i>Lupinus sp.</i>								1
<i>Phacelia heterophylla</i>								1

Species found in the vicinity of the quadrat:

Rosa woodsii
Viguiera multiflora
Potentilla gracilis
 **Aster bigelovii*
Chrysothamnus parryi
 **Hackelia floribunda*
Vicia americana
 **Erigeron speciosus*
Achillea millefolium
Chrysopsis villosa
Salix sp.
Symphoricarpos sp.

QUADRAT VIII

Species	1947	1948	1949	1950	1951	1952	1954	1969
Chaenactis alpina	32	2	5	3	2	3	8	
Taraxacum officinale	2	9	20	9	10	1	2	10
Artemisia dracunculus	1	1	1	4	8	14	20	2
Sitanion hystrix	2	2	1	1		5		4
Chrysopsis villosa	1	1	3	1	1	1		1
Vicia americana	3	2	2	1	1			11
Agropyron trachycaulum	2	2	2	10	1			1
Gilia aggregata	1	1	4	8	4	4		
Bromus polyanthus	2	5	4			1	1	12
Hackelia floribunda		4	3	2	2	8	4	
Penstemon strictus			1					
Capsella bursa-pastoris					2			
Phacelia leucophylla					1	5	2	
Epilobium paniculatum					10	5		
Polygonum aviculare						6		
Achillea millefolium							1	23
Chrysothamnus parryi								1
Grass (undet.)								3

Species found in the vicinity of the quadrat:

Eriogonum umbellatum
 *Chaenactis alpina
 *Phacelia heterophylla
 *Gilia aggregata
 Lepidium ramosissimum
 Aster bigelovii
 *Hackelia floribunda
 Potentilla gracilis
 Viguiera multiflora
 Agoseris glauca
 Viola nuttallii
 Rosa woodsii
 Erigeron speciosus
 Gayophytum nuttallii
 Polygonum douglasii
 Descurainia richardsonii
 Poa pratensis

QUADRAT IX

Species	1947	1948	1949	1950	1951	1952	1954	1969
+ Festuca thurberi	10	8	10	8	6	4	4	4
Artemisia dracunculus	32	28	14	18	22	28	20	5
A. scopulorum								1
Taraxacum officinale	16	4	2	1	1	1		20
Chrysothamnus								
viscidiflorus	2	1	1	1	2	1	1	3
Lupinus sericeus	4	3	1	1	1	1	1	
Lupinus sp.								1
Achillea millefolium	40	20	6	1	4		2	105
Polygonum aviculare	20	11				66	17	
P. douglasii								1
Agropyron trachycaulum	1		1	1	9			
Potentilla pulcherrima	2							7
Agropyron saundersii					4		6	5
Epilobium paniculatum			8		10			
Koeleria cristata			2		1		1	9
Hackelia floribunda			2					
Trisetum spicatum			1					
Penstemon strictus			1					
Chenopodium fremontii				12		8		
Lepidium ramosissimum				2				
Stipa columbiana					20	18	28	3
S. comata								2
Linum lewisii					1	4	8	
Festuca idahoensis						6	1	
Sitanion hystrix								3
++Antennaria microphylla								7
Vicia americana								4
Androsace septentrionales								56
Carex sp.								27
Erigeron speciosus								13
Grass (undet.)								10

Species found in the vicinity of the quadrat:

*Agropyron trachycaulum
 *Hackelia floribunda
 *Lepidium ramosissimum
 *Linum lewisii
 Arabis drummondii
 Gilia aggregata
 Castilleja linariaefolia
 Stipa columbiana nelsoni
 Eriogonum umbellatum
 *Chenopodium sp.
 Bromus polyanthus
 B. porteri Coult.

+ each clump counted as an individual plant

++each mat counted as an individual plant

QUADRAT X

Species	1947	1948	1949	1950	1951	1952	1954	1969
<i>Poa thurberi</i>	4	5	1	1	2	1	1	1
<i>Emisia darcunculus</i>	8	12	6	4	10	8	10	30
<i>E. tridentata</i>								1
<i>Triogonum umbellatum</i>	16	11	4	2	4	9	3	8
<i>Paraxacum officinale</i>	8	5		2	6	5		13
<i>Achillea millefolium</i>	7	4			1			21
<i>Chrysopsis villosa</i>			2	1	1			
<i>Agropyron trachycaulum</i>			1	2	1			
<i>Sitanion hystrix</i>			1	1	1			1
<i>Chrysothamnus sp.</i>				1	2	1	2	
<i>C. viscidiflorus</i>								2
<i>Koeleria cristata</i>				1				
<i>Stipa columbiana</i>					5	1		1
<i>Poa interior</i>					1	4	4	5
<i>Chenopodium fremontii</i>					4			
<i>Arabis drummondii</i>					3			
<i>Agoseris glauca</i>							2	4
<i>Carex sp.</i>								54
Grass (undet.)								5

Species found in the vicinity of the quadrat:

Stipa columbiana nelsoni
 **Agropyron trachycaulum*
 n. sp. *Arabis saundersii*
Linum lewisii
 **Chrysothamnus parryi*
Viguiera multiflora
Poa pratensis
Chaenactis alpina
Viola nuttallii
Hackelia floribunda
Senecio eremophilus
Gayophytum nuttallii
Erigeron speciosus
Vicia americana
Gilia aggregata
Potentilla pulcherrima
Lupinus sp.

The following table lists the frequencies in % of the plants found within the quadrats.

Species	1947	1948	1949	1950	1951	1952	1954	1969
<i>Chaenactis alpina</i>	80	80	80	60	80	70	60	40
<i>Taraxacum officinale</i>	60	80	70	80	80	90	70	80
<i>Hackelia floribunda</i>	0	10	30	20	30	40	30	20
<i>Sitanion hystrix</i>	30	30	40	40	40	30	30	100
<i>Gayophytum nuttallii</i>	0	0	0	0	20	20	10	0
<i>Chenopodium fremontii</i>	0	0	0	10	10	30	0	0
<i>Moldavica parviflora</i>	0	0	0	0	0	0	10	10
<i>Carex</i> sp.	0	0	10	0	0	0	20	40
<i>Polygonum aviculare</i>	10	10	0	10	10	40	30	0
<i>P. douglasii</i>	0	0	0	0	0	0	0	10
<i>Linum lewisii</i>	0	0	0	0	10	10	20	0
<i>Phacelia heterophylla</i>	0	0	0	0	10	10	20	20
<i>Chrysothamnus</i> sp.	0	0	0	10	10	10	20	
<i>C. parryi</i>	0	0	0	0	0	0	10	50
<i>C. viscidiflorus</i>	10	10	10	10	10	10	10	20
<i>Penstemon strictus</i>	10	10	30	10	30	10	30	30
<i>Bromus inermis</i>	0	0	0	0	10	10	10	0
<i>B. polyanthus</i>	10	10	10	0	0	20	10	70
<i>Gilia aggregata</i>	20	10	20	20	30	20	10	20
<i>Aster bigelovii</i>	0	0	20	10	20	10	0	20
<i>Agropyron trachycaulum</i>	30	20	50	50	50	20	0	30
<i>A. saundersii</i>	0	0	0	0	10	0	10	10
<i>Artemisia tridentata</i>	0	0	20	0	20	20	20	40
<i>A. dracunculus</i>	40	40	30	40	40	30	40	50
<i>A. scopulorum</i>	0	0	0	0	0	0	0	10
<i>Stipa columbiana</i>	0	0	0	0	30	30	20	20
<i>S. comata</i>	0	0	0	0	0	0	0	10
<i>Capsella bursa-pastoris</i>	0	0	0	0	10	10	0	0
<i>Erigeron speciosus</i>	10	10	0	0	0	0	0	10
<i>Agoseris glauca</i>	0	0	10	0	0	0	10	10
<i>Eriogonum coloradense</i>	0	0	10	10	10	10	10	0
<i>E. pauciflorum</i>	0	0	0	0	0	0	0	10
<i>E. umbellatum</i>	10	10	10	10	10	10	10	80
<i>Chrysopsis villosa</i>	10	10	20	20	20	10	0	20
<i>Vicia americana</i>	10	10	10	10	10	0	0	20
<i>Epilobium paniculatum</i>	0	0	10	0	20	10	0	0
<i>Achillea millefolium</i>	20	20	10	10	20	0	20	30
<i>Festuca thurberi</i>	20	20	20	20	20	20	20	20
<i>F. idahoensis</i>	0	0	0	0	0	10	10	0
<i>Lupinus</i> sp.	10	10	10	10	10	10	10	20
<i>Koeleria cristata</i>	0	0	10	10	10	0	10	10
<i>Trisetum spicatum</i>	0	0	10	0	0	0	0	0
<i>Lepidium ramosissimum</i>	0	0	0	10	0	0	0	0
<i>Poa interior</i>	0	0	0	0	10	10	10	10
<i>Arabis drummondii</i>	0	0	0	0	10	0	0	0
<i>Castilleja linariaefolia</i>	0	0	0	0	0	0	0	10
<i>Potentilla pulcherrima</i>	10	0	0	0	0	0	0	10
<i>Antennaria microphylla</i>	0	0	0	0	0	0	0	10
<i>Androsace septentrionales</i>	0	0	0	0	0	0	0	10
<i>Viola nuttallii</i>	0	0	0	0	0	0	0	10
Grass (undet.)	0	0	0	0	0	10	40	60

on:

The Floral Composition of the Quadrats

Previous work established that Chaenactis alpina is the pioneer species on unstable shale characterizing certain areas of the Gothic Earthflow. As the substratum became more stabilized, a decrease in the numbers of C. alpina was accompanied by an increase in the numbers of perennial forbs and grasses (Langenheim, 1956). The results of this study (1969) indicate a further decrease in the numbers of C. alpina. Quadrats I-IV were established in what was considered to be a C. alpina community in 1947 (Langenheim, 1956). Comparative figures for 1954 and 1969 show the following reduction in C. alpina plants within the quadrats: I, 4-1; II, 0-0 (C. alpina last recorded as appearing in this quadrat in 1951); III, 9-0; IV, 7-1.

In quadrats I, II and IV, increases in the number of perennial forb and grass species and the total number of individuals per unit area were observed. Quadrat III experienced a complete change in species composition and decreases in the number of species and total number of individuals per unit area from 1954 to 1969. Comparative figures for 1954 and 1969 show the following increases and decrease in the number of species: I, 3-8; II 2-7; III, 11-5; IV, 4-6. Comparative figures for 1954 and 1969 indicate the following increases and decreases in the total numbers of individuals: I, 7-15; II, 4-49; III, 44-6; IV, 16-18.

The presence of Artemisia tridentata was noted in the vicinities of quadrats I, II and IV and within quadrat III. It appears that the radical change in the floral composition of quadrat III is due to the

recorded there in 1954. Frequency figures for the four quadrats suggest the importance of the perennial grasses, Sitanion hystrix and Bromus polyanthus, and the perennial forb, Eriogonum umbellatum, in the revegetation of these bare areas. However, these species occur in relatively low densities within the quadrats.

The appearance, disappearance and reappearance of certain species during the years studied may indicate the essential chance occurrence of individuals on any local site (Langenheim, 1956). The survey of vegetation in the vicinities of the quadrats revealed that several plants once found within the quadrats now only appear near them. The presence of the same species within the quadrats during the previous years observed and not within the quadrat, but in its vicinity in 1969 supports the idea of chance occurrence on a local site.

The quadrats V-VIII were placed in a perennial forb community in which Chaenactis alpina was a characteristic constituent. Though not as abundant in these quadrats as in quadrats I-IV, C. alpina was well represented in 1947, but was near extinction by 1954 (Langenheim, 1956). In 1969, the numbers of C. alpina have decreased from 1-0 in quadrat VI, and from 8-0 in quadrat VIII, but have increased from 1-5 in quadrat V and 0-1 in quadrat VII. The edaphic conditions of quadrat V explain the increase in the number of C. alpina plants within it. The presence of large, unstable shale particles (Fig. 8) provides an environment in which a pioneer plant such as C. alpina can thrive. The five C. alpina plants, like many of the other plants in this quadrat, were seedlings. This indicates that the conditions of instability within quadrat V have prevented the development of

the mature plants. The one C. alpina plant in quadrat VII probably resulted from chance occurrence on a local site.

All four of the quadrats V-VIII show increases in the number of species from 1954 to 1969: V, 5-13; VI, 8-10; VII, 8-13; VIII, 7-10. Quadrat VIII, however, had larger numbers of species in the years before 1954. Quadrats V to VIII also indicate increases in the total numbers of individuals per quadrat from 1954 to 1969: V, 24-49; VI, 27-51; VII, 31-46; VIII, 38-68. In quadrats VII and VIII, the total numbers of individuals per quadrat were greater than 31 and 38, respectively, in the years before 1954.

The species occurring the most frequently in the perennial forb community quadrats are Taraxacum officinale, Sitanion hystrix, Bromus polyanthus, Agropyron trachycaulum, Eriogonum umbellatum, Chrysothamnus parryi, Gilia aggregata, Artemisia dracunculus, A. tridentata, Penstemon strictus, Phacelia heterophylla, Chrysopsis villosa and grass (undet.). Out of these, the ones with the highest densities are Taraxacum officinale, Sitanion hystrix, Bromus polyanthus, Eriogonum umbellatum and grass (undet.). Shrubs such as Artemisia tridentata and Chrysothamnus parryi and, in some cases, the mat-forming Eriogonum umbellatum may have relatively low densities, but their coverage is much greater than many of the other perennial forbs and grasses.

Langenheim (1956) defined the perennial forb stage as when the pattern of the community is dominated by such forbs as *Artemisia dracunculus, *Gilia aggregata, Eriogonum coloradense, Erigeron speciosus, *Penstemon strictus, Achillea lanulosa, Lathyrus leucanthus, Vicia americana, and the grasses, *Sitanion hystrix, *Agropyron trachycaulum, and Bromus inermis. Five of these (the ones starred) were important

ents of the perennial forb community in 1969.

Langenheim (1956) stated that there may be fluctuations in the number of species within the perennial forb community and their relative abundance depending upon the means of seed dissemination and the local environmental conditions. Taraxacum officinale, Artemisia dracunculus, Gilia aggregata, Sitanion hystrix and Agropyron trachycaulum were consistently present in the quadrats during the seven years of her study. These same species continued to be present in the four quadrats in this study. They may form the backbone of the perennial forb community, with other species such as Erigeron speciosus, Penstemon strictus, Phacelia heterophylla, Vicia americana, Chrysopsis villosa, Eriogonum coloradense and Achillea millefolium augmenting the floral composition of the quadrats and their vicinities from year to year. Bromus polyanthus, Chrysothamnus parryi and Eriogonum umbellatum were especially important components of the perennial forb community in the present study.

Large patches of Artemisia tridentata were found quite close to quadrats VI and VII, and a smaller stand occurred near quadrat V. A. tridentata bushes appeared within quadrats VI and VII. The three bushes within quadrat VII may indicate the development of a sagebrush stage.

Quadrats IX and X, located in the fescue grassland of Area II, showed increases in the numbers of species present and the number of individual plants per quadrat. Comparative figures specifying the increases in the numbers of species for 1954 and 1969 are as follows: IX, 11-20; X, 6-13. Quadrat IX especially reflected the presence of new species with relatively high densities. Comparative figures

ating the large increases in the numbers of individuals per quadrat for 1954 and 1969 are the following: IX, 85-291; X, 22-150.

The following appeared in both of the grassland quadrats:

Festuca thurberi, Artemisia dracunculus, Taraxacum officinale, Achillea millefolium, Chrysothamnus viscidiflorus, Carex sp., Stipa columbiana, Sitanion hystrix and grass (undet.). From the above list, Achillea millefolium, Carex sp., Taraxacum officinale and Artemisia dracunculus have the highest densities. Density figures for the fescue grassland community are often misleading because different species cover varying amounts of space within the sampling area. Individual plants of the following species - Chrysothamnus viscidiflorus, Festuca thurberi and Lupinus sp. - cover a much larger area than many of the abundant Achillea millefolium seedlings and Carex sp. plants.

Langenheim (1956) found that Chrysothamnus viscidiflorus, C. parryi, Lupinus sericeus, Festuca thurberi, and Artemisia dracunculus persisted in the quadrats during her seven year study. All of these * except C. parryi were found still present in the grassland quadrats. These species are significant components of the fescue community with such forbs as Taraxacum officinale, Achillea millefolium, Carex sp., Eriogonum umbellatum and the grasses, Sitanion hystrix, Agropyron trachycaulum, A. saundersii, Stipa columbiana, Koeleria cristata and Poa interior usually playing more subordinate roles.

Langenheim (1956) commented that her study showed a relatively wide fluctuation in the density of the subordinate species. The

* In 1969, the Lupinus sp. of quadrat IX was not in flower and no positive species identification was made.

ation was partially attributed to biotic factors such as the grazing of cattle. There are large differences in the 1954 and 1969 densities of Artemisia dracunculus in quadrats IX and X; also Stipa columbiana and Achillea millefolium in quadrat IX. However, no records of the quadrat densities from 1954 to 1969 exist and, because of the fifteen year interval, the significance of such density fluctuations is questionable.

Artemisia tridentata was recorded as appearing for the first time in quadrat X. A patch of sagebrush was also found close to the quadrat (Fig. 13). It is not uncommon for shrub societies containing A. tridentata to occur within stands of fescue (Langenheim, 1962). However, the possibility that the sagebrush may be invading the slump block as well as parts of the actual earthflow should not be ignored.

As previously mentioned, difficulties were encountered in re-charting the grassland quadrats due to the lack and obscurity of the permanent quadrat markers. In this study, the boundaries of the quadrats IX and X had to be approximated. The possibility exists that the data for these quadrats may be inaccurate because of the problems involved in relocating the exact quadrat boundaries. However, the vegetation within the vicinities of each of the quadrats appeared to be fairly homogeneous. The vegetation pattern of these quadrats in 1969 does bear some resemblance to previous records. The approximated quadrats, therefore, may reveal a satisfactory picture of the changes occurring in the species populations of the fescue community.

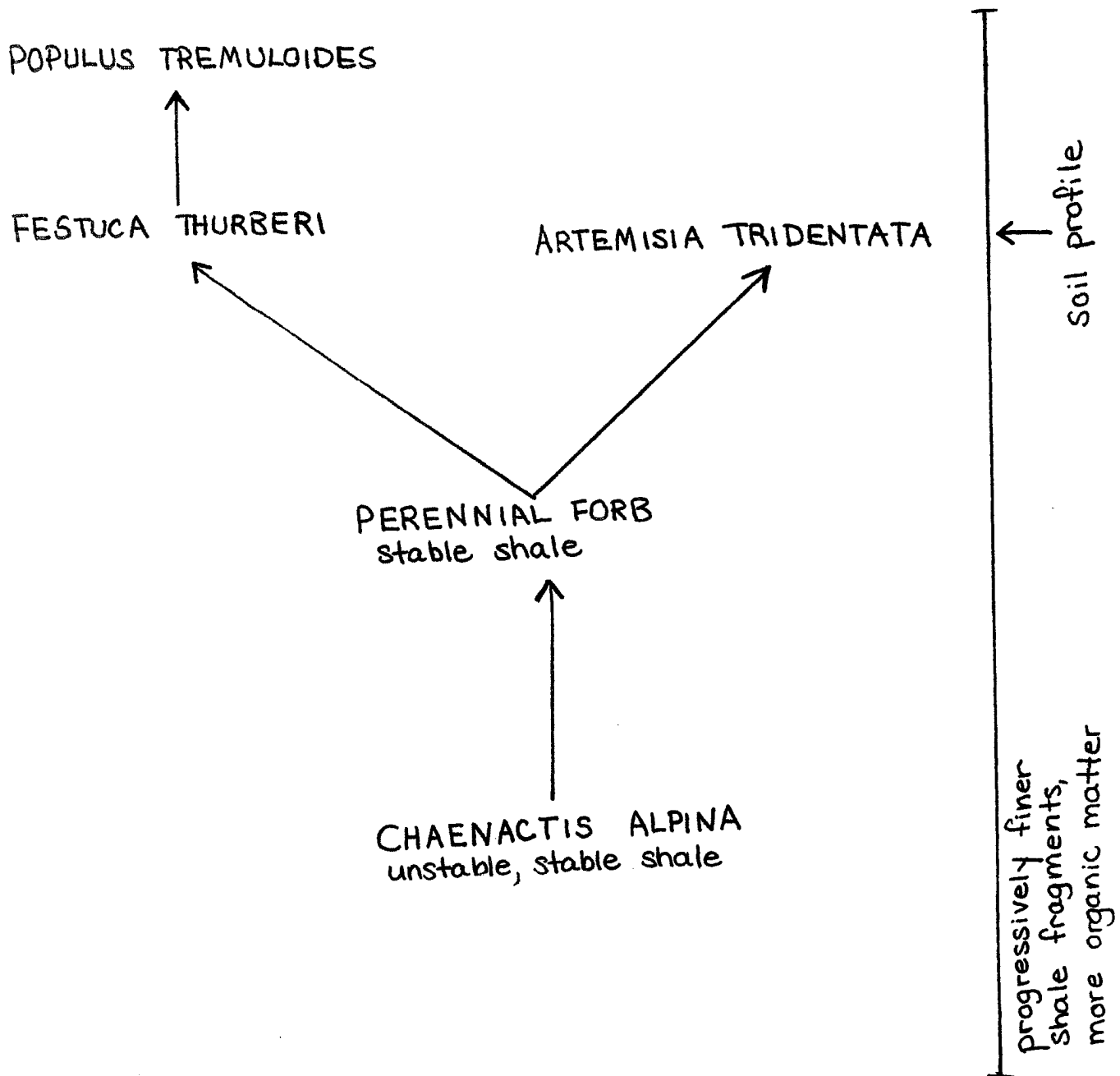
Successional Relationships

In her 1956 paper, Langenheim proposed a tentative scheme for

Successional relationships in the revegetation of the Gothic Earthflow (Fig. 14). A community dominated by Chaenactis alpina appears as the pioneer on the unstable shale. It is followed by the emergence of a perennial forb stage in which numerous forbs and grasses are characteristic. Either an Artemisia tridentata climax or Festuca thurberi subclimax may follow the perennial forb and grass stage. In the event a Festuca thurberi stage emerges, a Populus tremuloides climax could ensue.

From 1947 to 1954, Langenheim (1956) witnessed the changes in quadrats I-IV that indicated the development of a perennial forb and grass community in what was originally (1947) a Chaenactis alpina community. Quadrats V-VIII, established in a perennial forb community, showed decreases in the number of C. alpina plants; the appearance, disappearance and reappearance of certain perennial forbs and grasses and fluctuations in their densities. In the grassland quadrats, the dominant species were relatively stable as far as yearly appearance within the quadrat in relatively unchanged densities, but fluctuations occurred in the density of the subordinate species. Since many of the perennial forbs and grasses such as Artemisia dracunculoides, Taraxacum officinale, Achillea millefolium, Eriogonum umbellatum, Chrysothamnus sp., Sitanion hystrix and Agropyron trachycaulum are characteristic of not only the perennial forb community but the fescue and sagebrush communities as well, it was difficult to speculate on what direction the revegetation of the earthflow would take. A transect line study of the earthflow vegetation made by Leslie Foster in 1966 concluded that there were no great changes in the vegetation pattern since the completion of Langenheim's studies.

Figure 14
Successional Relationships Involved in the Revegetation of the Gothic
Earthflow (Langenheim, 1956):



Langenheim (1966) recognized that the appearance of Artemisia tridentata in two of the permanent quadrats may indicate movement in the direction of a sagebrush stage. The present study found A. tridentata in four of the permanent quadrats and in the vicinity of four of the other six quadrats.

The Artemisia tridentata community type ranges altitudinally from 8,500 to 12,000 feet but forms an important vegetation zone only from 8,500 to 9,500 feet in the Crested Butte Area. It is in transition with fescue grassland in several localities. A. tridentata grows favorably on shale substratum such as that of the Gothic Earthflow. Within the sagebrush community, Festuca thurberi is of secondary importance. The other grasses, Stipa columbiana, Bromus frondosus and Agropyron trachycaulum may also characterize the community. The shrubs, Chrysothamnus viscidiflorus and C. parryi, and the forbs, Arenaria congesta, Eriogonum neglectum (umbellatum) and Lupinus sericeus, are common (Langenheim, 1962).

The Artemisia tridentata in the earthflow quadrats occurred with some of the above associates: Stipa columbiana, Agropyron trachycaulum, Chrysothamnus viscidiflorus, C. parryi and Eriogonum umbellatum, but was only associated with Festuca thurberi in quadrat X, located in the fescue grassland. A general survey of the earthflow vegetation patterns revealed that Festuca thurberi is found only in Area II and the slump islands of vegetation in Area III. The bunch grass has not yet established itself on the bare shale portions of the earthflow. A brief survey of the vegetation of an older region (located five miles from Gothic off the road from Gothic to Crested Butte) where mass movement had occurred was made. An extensive stand of Artemisia tridentata was found in quadrat.

data was found upon it.

In conclusion, the shale substratum of the Gothic Earthflow has been sufficiently stabilized and enough soil development has taken place to support the growth of a large number of perennial forbs and grasses. This study found Sitanion hystrix, Bromus polyanthus, Eriogonum umbellatum, Taraxacum officinale, Artemisia dracunculus, and Chrysothamnus parryi to be the most important constituents of the perennial forb and grass community.

The following factors: 1. the appearance of Artemisia tridentata in four of the permanent quadrats and in the vicinity of four of the other six; 2. the apparent restriction of Festuca thurberi to Area II and part of Area III; 3. the ability of Artemisia tridentata to move into areas where mass movements have occurred, suggest that there is a trend toward the development of a sagebrush stage. However, only future studies can confirm this.

Summary:

The presence of certain topographic, stratigraphic and structural features, combined with excessive amounts of soil water, resulted in an extensive earthflow near Gothic, Colorado, in 1923. Dr. Jean H. Langenheim established ten one meter by one meter permanent quadrats on the earthflow for studying changes in species populations and possible successional relationships during the years 1947-1954, with the exception of 1953.

In the present study, the quadrats were relocated and restaked. Their vegetative composition was analyzed as previously done. Densities and frequencies were computed from the data gathered from each quadrat.