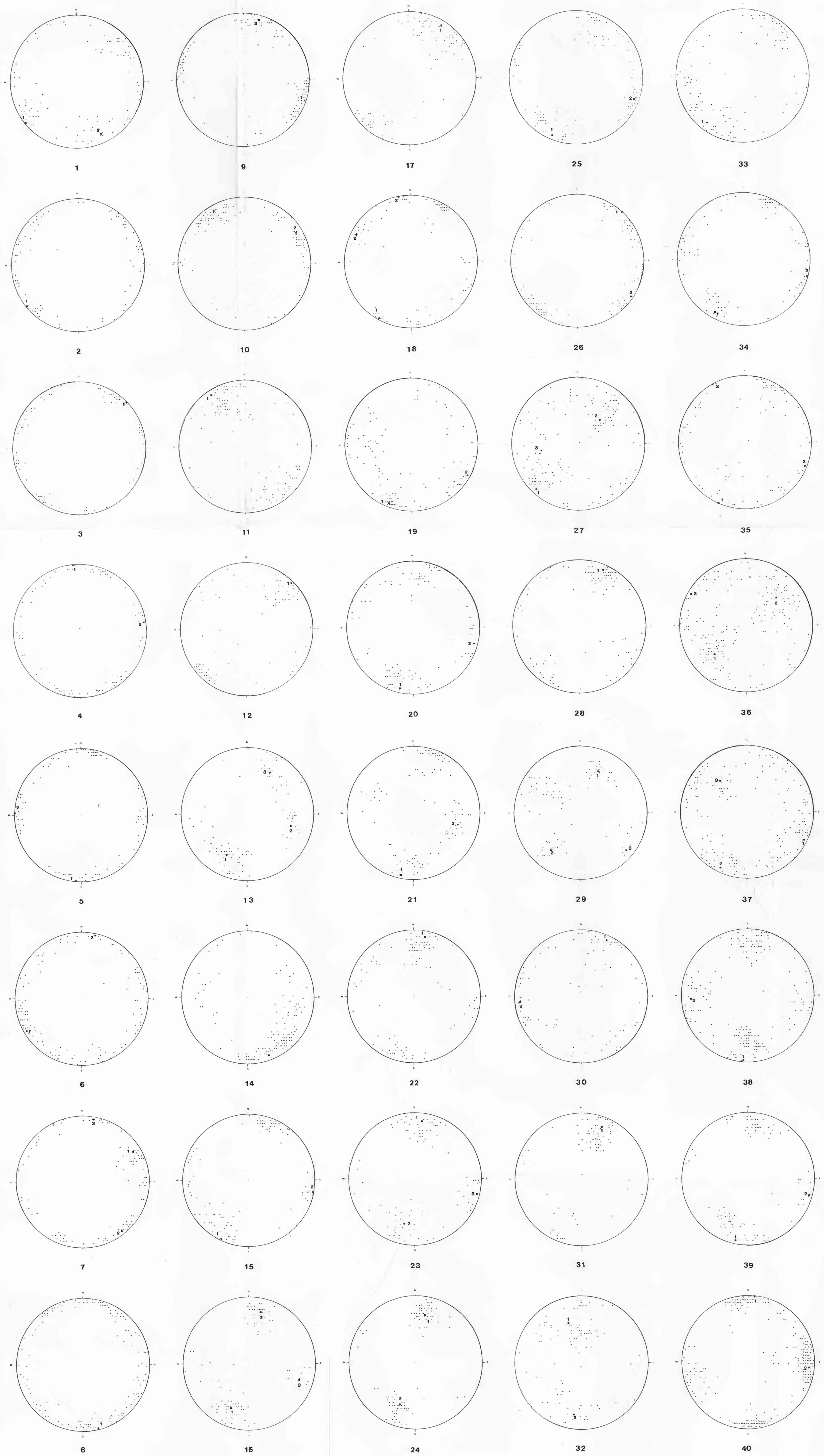
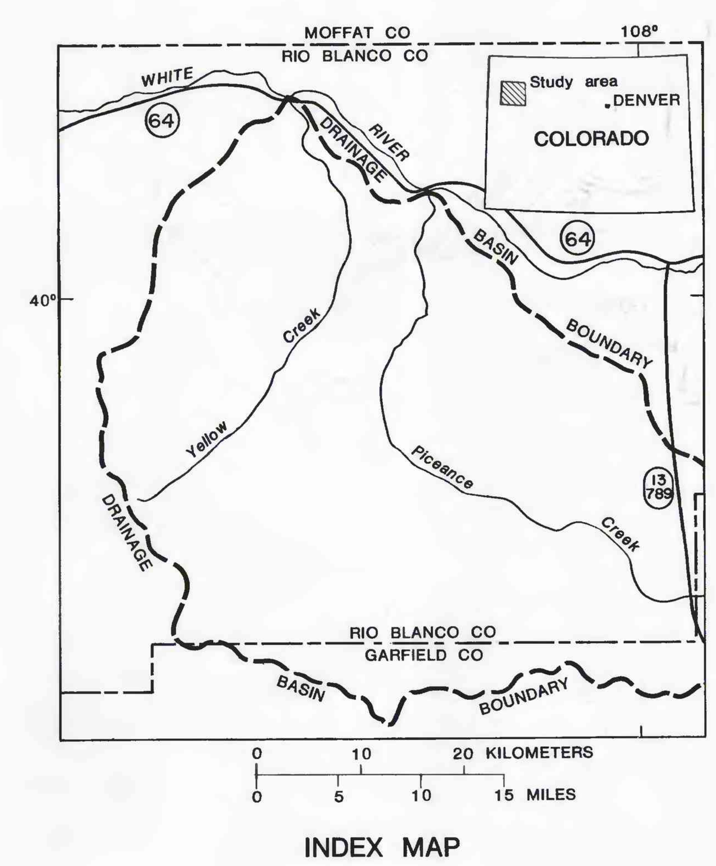


Figure 1-- Upper hemisphere stereonets for Piceance Creek basin field stations showing original data and mean strike and dip of joint sets.

Table 1.--Summary of measurements on joint sets, Piceance Creek basin, northwestern Colorado

Field site	Number of observa-tions	Number of joint sets	Percent of Sample	Strike in degrees	Dip in degrees	Radius of cone of confidence in degrees
1	108	1	34.3	142	89	4.15
		2	15.7	66	78	7.79
2	108	1	49.1	142	88	3.62
3	108	1	54.6	318	89	4.11
4	108	1	73.1	264	90	4.95
		2	13.0	353	88	5.69
5	108	1	51.9	94	90	3.67
		2	34.3	181	90	4.25
6	132	1	38.6	151	85	4.81
		2	6.1	283	87	4.85
7	108	1	20.4	331	79	3.28
		2	13.9	51	85	5.60
		3	5.6	282	88	21.13
8	198	1	58.1	76	88	4.49
9	144	1	62.5	19	88	2.98
		2	17.4	286	82	4.04
10	144	1	46.5	240	81	2.68
		2	36.1	330	82	2.92
11	123	1	65.0	238	84	4.40
12	108	1	67.6	315	86	2.75
13	108	1	29.6	118	58	4.28
		2	18.5	14	60	5.26
		3	13.9	299	63	4.15
14	144	1	30.6	70	82	5.25
15	108	1	61.1	115	87	3.76
		2	16.7	11	89	5.89
16	106	1	43.4	113	63	7.71
		2	29.2	283	69	3.46
		3	7.1	17	70	9.24
17	111	1	75.9	306	81	3.40
18	108	1	39.8	120	89	1.56
		2	18.5	208	83	4.32
		3	13.0	261	90	3.45
19	144	1	34.0	110	84	1.60
		2	11.1	29	85	5.48
20	114	1	57.9	103	84	4.33
		2	7.0	14	84	9.68
21	108	1	34.3	102	85	5.01
		2	20.4	14	58	5.19
22	108	1	69.6	280	80	4.40
23	108	1	41.7	278	78	4.59
		2	13.9	103	59	4.99
		3	6.5	13	85	9.26
24	108	1	38.0	281	74	3.40
		2	31.5	111	60	2.67
25	146	1	37.0	114	83	4.00
		2	30.8	21	86	2.41
26	147	1	55.8	313	90	2.70
		2	15.6	34	87	4.37
27	146	1	29.2	134	84	4.30
		2	13.7	313	43	3.97
		3	5.6	171	50	11.75
28	108	1	56.5	291	83	4.01
29	109	1	29.4	294	60	3.11
		2	12.0	129	63	4.74
		3	11.0	39	81	3.97
30	108	1	26.8	297	83	4.46
		2	22.2	176	83	6.30
31	108	1	69.4	291	75	3.18
32	106	1	48.1	253	53	6.70
		2	16.0	100	70	6.93
33	111	1	62.2	127	81	5.26
34	108	1	37.0	118	84	4.26
		2	35.2	15	89	4.51
35	109	1	27.5	114	90	3.93
		2	8.3	21	87	4.46
		3	7.3	241	90	13.95
36	216	1	24.1	137	57	3.11
		2	18.1	319	53	4.21
		3	9.7	211	84	9.08
37	202	1	28.7	25	86	4.89
		2	27.2	116	79	3.69
		3	6.4	228	49	4.41
38	216	1	37.5	94	89	4.43
		2	10.2	177	75	6.36
39	110	1	66.4	101	86	5.20
		2	10.0	14	88	6.30
40	185	1	54.6	275	89	1.31
		2	38.9	4	81	2.53



INDEX MAP

INTRODUCTION

Joints are fractures in bedrock along which no appreciable movement has occurred. A group of more or less parallel joints is called a joint set and is commonly formed by rock adjustment to stress. In order to study patterns of joint sets in the Piceance Creek basin two types of data were collected and plotted separately. First, rectilinear to gently curvilinear surface features that are thought to be structurally controlled were mapped from aerial photographs of two different scales (sheet 1, fig. 1). Next, joint sets were derived from statistical analysis of field measurements (sheet 1, fig. 2).

This study of surface joints is an initial attempt to improve our knowledge of fracture systems in the Piceance Creek basin. The abundance, orientation, and size of fractures in bedrock appear to control the movement of ground water in the basin (Dietz, et. al., 1977).

The authors gratefully acknowledge the advice and support of Earl Verbeek and Frank Welder of the U.S. Geological Survey.

AIRPHOTO LINEAMENTS

An alinement of distinct photographic features, or an linear expression of color or tonal contrast in an aerial photograph was the main criterion for selecting lineaments. Information was collected from black and white photographs at a scale of 1:60,000 and color infra-red photographs at a scale of 1:24,000. Three kinds of lineaments were distinguished. First, lines of vegetation were mapped from the larger scale color imagery; ground observations showed that nearly all of these lineaments follow the surface trace of joints. Second, photo lineaments identified by their topographic expression were prominent on both sets of aerial photographs. Most of these lineaments trend either WNW or NW; several correspond with previously mapped faults. Selected ground checking indicates that most of the other topographic lineaments also represent the surface trace of normal faults. A third class of photo lineaments is expressed in the unusual geometry of the tributary streams of Piceance and Yellow Creeks. Alined and near-parallel tributaries have anomolously long, straight valleys that trend NNE in the eastern part of the basin and more nearly NE in the western part. Although structural control is implied by the linear and parallel nature of these drainages, field data suggest that neither faulting nor jointing are responsible for the orientation of the tributary streams. This class of photo lineament should not be considered as relevant structural data in this basin until a relationship can be established between structural data collected from the field and the alined stream valleys.

MEASURED JOINT SETS

Strike and dip measurements on surface joints were made at each of forty field stations shown on sheet 1, figure 2. Transects were made along an outcrop and every exposed joint was recorded until at least 100 measurements were made. A computer program was used to plot poles to the joint planes at each station on upper hemisphere equal-area stereonets (sheet 2). The program uses a Poisson distribution model to segregate the data into clusters which represent joint sets (Mahtab, M. A. and others, 1972). For each defined joint set the program determined the mean strike and dip and the radius of the cone of confidence (see table 1) using Arnold's hemispherical normal distribution. The cone of confidence is a confidence interval that defines the area within the stereonet where the mean strike and dip of each joint set is expected to lie. At each of the forty field stations shown on sheet 1, figure 2 the strike directions are given for each joint set (table 1) that comprises more than five percent of the total measurements at each location. The length of each line indicates the percentage of the total population that a particular joint set represents.

The primary and secondary joint sets were also determined at twenty-eight unnumbered locations and are shown on sheet 1, figure 2. At these localities, bedrock outcrops which had few exposed joints, fewer than 100 measurements were made and averaged. The separation of joint sets commonly was visually apparent, but the information gathered at these locations may be less reliable than the statistically derived joint sets at each of the numbered field stations.

Joint sets containing large, tightly spaced joints are considered primary, while sets containing less well developed joints are considered as secondary. In comparison to secondary sets, joints of primary sets tend to have a longer length of trace, a greater vertical extent, and are more nearly parallel to each other. The primary joint sets are usually perpendicular to each other.

Lithology is a very important factor in joint formation. The greatest density of joints is found in barren marlstone and dolomite. Joint density decreases as the kerogen content of the "oil shales" increases. This happens because of the increase in rock ductility associated with increasing proportions of bituminous matter in the rocks. The joint density in siltstone and sandstone is generally less than in barren marlstone and dolomite. In the shale, dolomite, and marlstone of the Green River Formation, joints typically are perpendicular to bedding. In sandstone and siltstone of the Uinta Formation, joints form at high angles to bedding (60-70 degrees) and often form conjugate sets. Both types of joints may be well developed at the same outcrop, indicating that different rock types respond differently to the same stress field.

PATTERN OF JOINTING

From sheet 1, figure 2, it can be seen that the most prominent joint set throughout the Piceance Creek basin strikes west-northwest. The second most prominent direction is north-northeast. From the southeastern to the northwestern portion of the basin the strike of the major joint set swings from approximately 280 to 315 degrees. Along Cathedral Bluffs, at the western edge of the basin, major, subvertical joint sets have developed parallel to the cliff face, probably in response to unloading.

There is a strong parallelism between the strike of the major joint sets and the principal normal faults in the basin. This indicates that both kinds of features may have formed in a stress environment in which the least principle stress was oriented north-northeast. However, data are not yet available to confirm similar ages or a common origin in the same stress field.

Study of air photographs and satellite imagery of the areas bordering the Piceance Creek basin indicates that lineaments and possible faults whose directions parallel those of the prominent joint directions within the basin can be traced to the west and north of the basin. These regional trends may reflect epirogenic movements which took place in late Tertiary and possibly early Quaternary times.

The age (or ages) of jointing remain uncertain. There is not sufficient data to relate joint sets to the low amplitude folds within the basin and some field evidence suggests formation of some joints may have occurred before the sediments were completely lithified. Several massive rotated slump blocks are found in sandstones of the Uinta Formation; joints in these blocks are perpendicular to bedding and appear to have formed before the blocks were rotated.

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MAP OF JOINT SETS AND AIRPHOTO LINEAMENTS OF THE PICEANCE CREEK BASIN, NORTHWESTERN COLORADO

By
Rodney S. Smith and John W. Whitney
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