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PALEOMAGNETISM AND ANISOTROPY OF MAGNETIC SUSCEPTIBILITY OF THE TOODOGGONE FORMATION, BRITISH COLUMBIA
(94E)

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INTRODUCTION AND OBJECTIVES

The Toodoggone Formation is a succession of subaerially erupted ash flows, lava flows and associated pyroclastic rocks in north-central British Columbia that was constructed along the eastern margin of the Stikine Terrane in Early to Middle Jurassic time (Diakow, 1990; Diakow *et al.*, 1991). A field sampling program was conducted in late July and early August of 1991 with the objective of deciphering important geologic processes from the patterns of magnetic characteristics recorded in these strata (Figure 1-13-1). The specific magnetic characteristics are the natural remanent magnetization (NRM) and the anisotropy of magnetic susceptibility (AMS).

Paleomagnetic directions provide two pieces of regional tectonic information. Primary paleomagnetic inclinations, when compared to reference inclinations estimated from time-equivalent rocks of the North American craton, provide evidence for or against latitudinal displacement. Paleomagnetic results from Hazelton Group rocks exposed farther south in the Intermontane Belt suggest no detectable northward displacement (Irving and Wynne, 1990; Vandall and Palmer, 1990). Data from the Toodoggone Formation would serve to substantiate the results of previous workers and extend the conclusion to a larger part of the Stikine Terrane. Departures from the expected paleodeclination, also estimated from time-equivalent rocks of the craton, provide evidence for block rotation which may accompany fault displacement. Rotations about vertical axes, manifested by declination anomalies, appear to characterize Hazelton rocks at the latitude of 55°N near the eastern and western margins of the Stikine Terrane (Monger and Irving, 1980; Vandall and Palmer, 1990). Paleomagnetic results from the Toodoggone River area would test whether this mode of deformation also characterizes the Stikine Terrane at higher latitudes.

The paleomagnetic method depends on the remanent magnetic properties of rocks. A second magnetic property, magnetic susceptibility and its anisotropy, is proving useful in determining the fabric of rocks. With respect to ash-flow tuffs, the minimum susceptibility axis commonly coincides with the pole to foliation and the maximum susceptibility axis is aligned along the direction of flow (Ellwood, 1982; Knight *et al.*, 1986; MacDonald and Palmer, 1990; Palmer *et al.*, 1991; Hillhouse and Wells, 1991). The presumption is that nonspherical magnetite particles achieve a preferred dimensional alignment in the horizontal flow phase of ash-flow emplacement. This dimensional alignment is expressed by the anisotropy of magnetic susceptibilty and is measured in the same samples used for the paleomagnetic work. The AMS method offers the potential of inferring the locations of source vents of ash flows when allowance is made for possible rotations inferred from the paleomagnetic data.

FIELDWORK

Outcrops along and near the private road network maintained by Cheni Gold Mines Inc. and International Shasta Resources Inc. were examined with the object of: (1) examining stratigraphic variations in the magnetic parameters of the Toodoggone Formation, (2) selecting outcrops free of visible hydrothermal alteration, and (3) locating outcrops where flow-compaction foliations or flow contacts could be observed. The latter data are needed to provide a paleohorizontal reference for the axial and vector magnetic data. Criteria (2) and (3) were met at eight outcrops. At two outcrops in Metsantan lava flows attitudes could not be determined with certainty but samples were nevertheless collected for polarity information. At each of these ten outcrops, five to eight independently oriented core samples were obtained using sun and magnetic compasses and a clinometer. Four outcrops are of the Metsantan member, two of the Attycelley member and four of the Saunders member, the stratigraphically highest member of the Toodoggone Formation. Ash-flow tuffs from the lowest member of the formation were not examined because of inaccessibility.

LABORATORY METHODS

One or more standard paleomagnetic specimens were prepared from each of the 63 oriented cores. All cores were cut into specimens with height to diameter ratios of 0.85. Measured volumes and masses of all specimens were used to calculate dry-weight densities, the outcrop means of which are recorded in Table 1-13-1. Subsequent to measurement of initial natural remanent magnetization, but prior to demagnetization experiments, the anisotropy of magnetic susceptibility was measured in the specimens employing a Sapphire Instruments SI-2 low-field instrument. Four repeat measurements of each of six orientations was made. After the susceptibility measurements were completed, the specimens were stored inverted in the earth's field to provide a

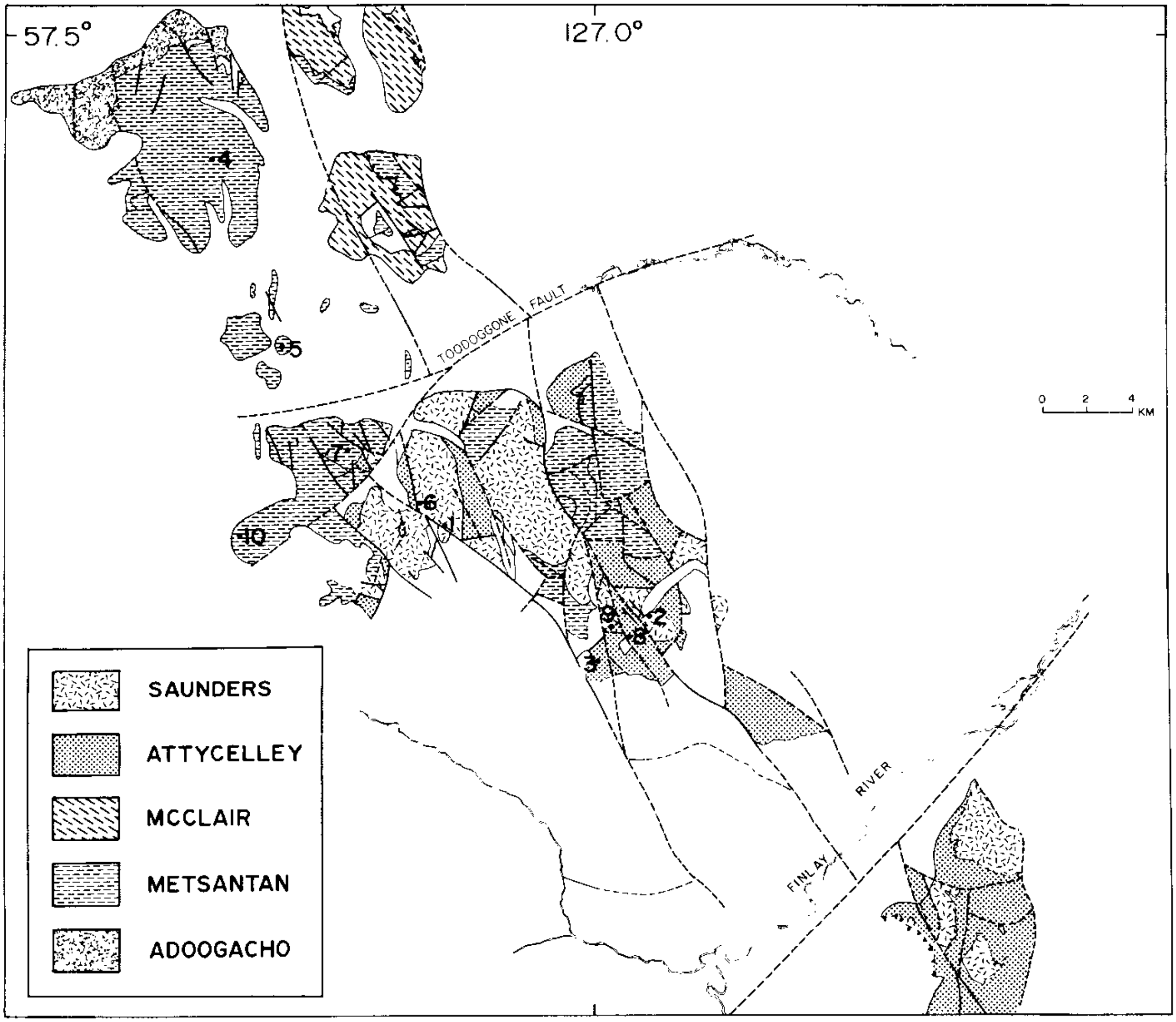

Figure 1-13-1. Geological map of the Toodoggone mining district simplified from Map 1 of Diakow (1990). Numbers identify the locations of sample sites.

storage test of remanence stability. Demagnetization experiments testing the stability of the natural remanent magnetism have yet to be carried out. The results that we present here are those of the AMS measurements and the field-measured structural elements.

RESULTS AND CONCLUSIONS

Foliation is very weakly developed in these rocks; at many localities none is visible in outcrop. In many ash-flow tuffs, collapsed pumice fragments form a eutaxitic structure and thus define a flow-compaction foliation. Although the Toodoggone tuffs are well compacted (*see* densities in Table 1-13-1), most are pumice-poor, crystal-rich tuffs.

The AMS axial ratios (Table 1-13-1) emphasize two points: the magnetic anisotropy is weak and the fabrics are oblate. These results are not unexpected given the weakly developed foliations noted above and the general absence of observed lineations in these rocks.

The bulk susceptibilities (Table 1-13-1) have a broad range of values. In magnetite-bearing rocks we find that the anisotropy of magnetic susceptibility cannot be measured with accuracy when the bulk susceptibility is less than 0.5×10^{-3} SI units. However the outcrops in the Toodoggone Formation with values of bulk susceptibility below this value have reddened feldspars or were characterized by a pink drilling return water, suggesting that hematite is the magnetic phase in these rocks of low susceptibility.

Additional experiments will be carried out to test whether the AMS patterns (Figure 1-13-2) are meaningful. Outcrops 5 and 10 are lava flows for which AMS axes are not likely to be well grouped; indeed they are not (Figure 1-13-2).

TABLE 1-13-1
ANISOTROPY OF MAGNETIC SUSCEPTIBILITY DATA, TOODOGGONE FORMATION

Unit	Site	ρ	K (10^{-3})	K_1/K_2	K_2/K_3	K_1 D°	K_1 I°	K_2 D°	K_2 I°	K_3 D°	K_3 I°
Saunders	1	2.63	43.4	1.014	1.044	281	07	190	03	091	84
Saunders	2	2.71	37.0	1.011	1.024	250	21	354	35	135	53
Attycelley	3	2.65	.366	1.016	1.015	346	24	069	12	148	48
Metsantan	4	2.50	.813	1.012	1.018	062	03	343	14	213	84
Metsantan	5	2.56	.288	1.013	1.021	357	00	084	21	250	68
Saunders	6	2.50	11.8	1.007	1.023	251	41	342	04	081	51
Metsantan	7	2.51	8.42	1.008	1.018	279	22	188	05	074	65
Attycelley	8	2.66	35.7	1.008	1.050	325	50	096	30	204	24
Saunders	9	2.70	7.09	1.009	1.013	056	24	320	13	204	70
Metsantan	10	2.55	.190	1.019	1.017	323	05	045	35	224	62

Notes:

ρ is the average density of the samples at the site in g/cm^3.

K is the site-mean volume susceptibility in SI units × 10^{-3}; $k = (K_1+K_2+K_3)$

K_1, K_2, K_3 are axes of maximum, intermediate, minimum susceptibility, respectively.

D°, I° are declination and inclination in degrees, respectively, of the axial means which are computed by the method of Scheidegger 1965).

K_1/K_2 and K_2/K_3 are ratios of susceptibilities along the axes indicated.

Outcrop 3, which also has weak bulk susceptibility, has dispersed AMS axes (Figure 1-13-2) but the mean of the minimum axes (K_3, Table 1-13-1) agrees quite well with the pole to foliation at this site (Figure 1-13-2). This suggests that a signal is recovered although it may be contaminated by random noise.

Where the bulk susceptibilities are high, the AMS patterns are generally more coherent (Figure 1-13-2). At outcrops 1, 4 and 6 there is good agreement between K_3 axes and field-measured foliation F. Outcrops 2 and 7 show small angular offsets between K_3 axes and foliation (Figure 1-13-2); this may reflect a particle imbrication. Outcrops 8 and 9 have well-defined magnetic fabrics but the visible fabrics are complex. At outcrop 8, a secondary shear fabric may dominate the primary fabric; at outcrop 9, two foliations were measured, one of which penetrated volcanic clasts. Here there is no correspondence between field-measured fabric and the AMS axes (Figure 1-13-2).

The best groupings of the maximum susceptibility axes (K_1) are at outcrops 1, 2, 8 and 10. At outcrops 6, 7 and 9 the maximum and intermediate axes form girdle distributions. These latter patterns are common in rocks with small magnitude differences between K_1 and K_2 axes; that is oblate fabrics. Such data are best represented by tensor averaging methods (Ernst and Pearce, 1989); those results will be published at a future date. In a preliminary analysis we have taken the preliminary axial averages of K_1 axes (Table 1-13-1) and rotated these by the the value of dip about the line of strike of the field-measured foliations.

Assuming no initial dip is present, this procedure restores the K_1 axes to the paleohorizontal. The azimuths of the K_1 axes may then be used to infer paleoflow and the data presented in the form of a rose diagram (Figure 1-13-3). The dominant 'flow' modes have an east-west trend suggesting a north-south array of source vents. Diakow (1990, page 114) inferred that the Saunders member was erupted from a regional fracture system thought to coincide closely with the Saunders-Wrich fault which trends 330°. Thus our results are in general agreement with his inference.

Our future work will include measurements of the paleomagnetism to evaluate the possibility of regional and local rotations and latitudinal displacements. Work on the AMS and its significance to source areas and to structural movements will also be continued. These results will be compared with the paleomagnetic results for a better understanding of the volcanic and structural processes which have affected this region of the Stikine Terrane.

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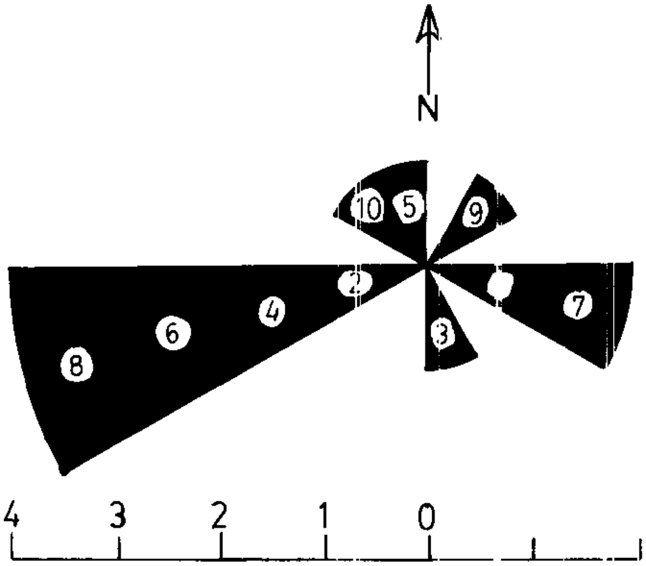

Figure 1-13-3. Rose diagram of downward directions of average K_1 axes corrected for tilt of foliation; numbers in sectors refer to outcrops. The radius of each sector is proportional to the number of observations. Six of the ten outcrops are consistent with east-west flow axes.

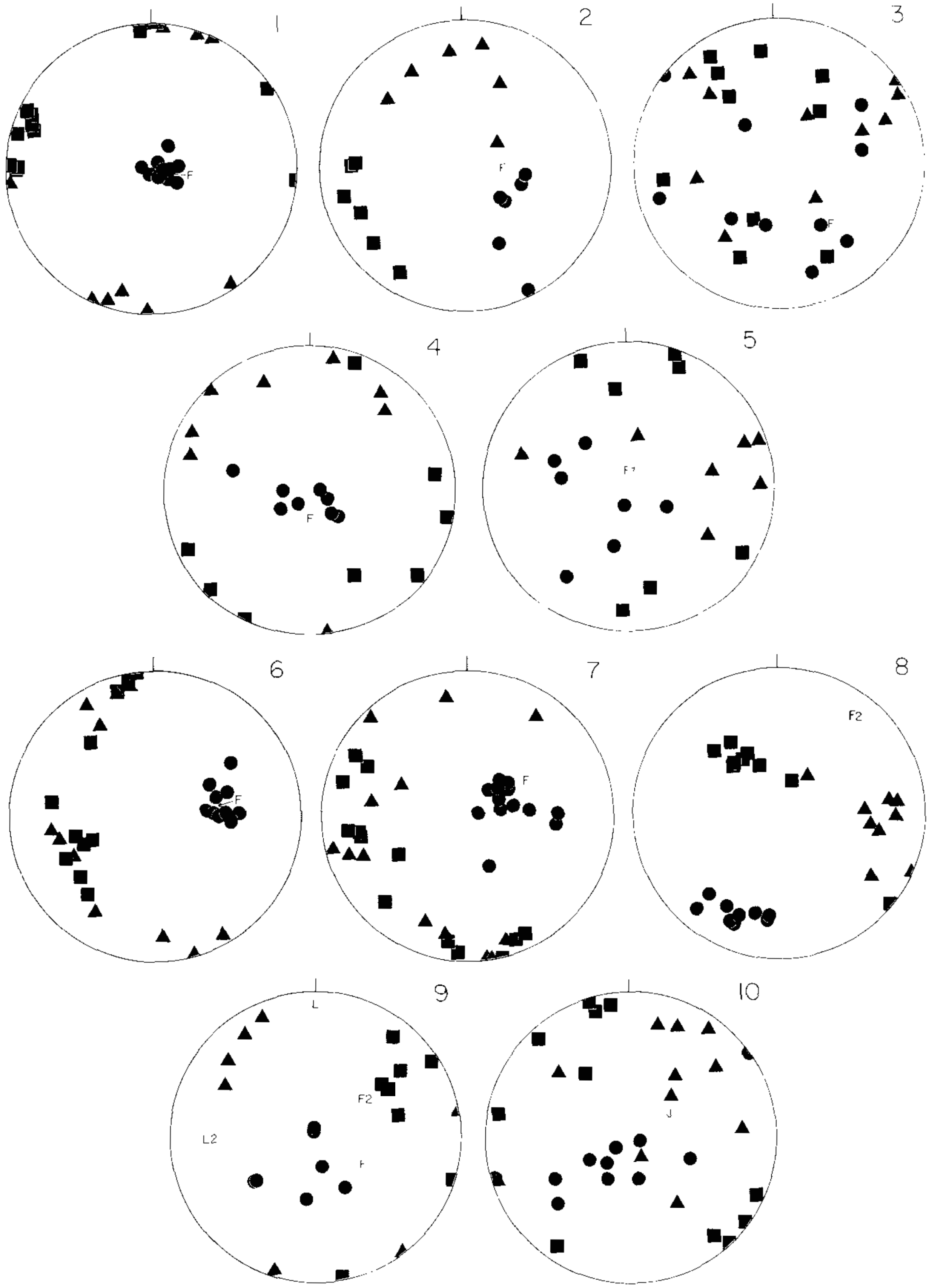

Figure 1-13-2. Equal-area stereograms showing K_1 axes (squares), K_2 axes (triangles) and K_3 axes (circles) at each of the ten sampled outcrops. F and L are field-measured foliation and lineation respectively. F_2 is foliation interpreted to be secondary. At outcrop 9, L_2 is the lineation defined by the intersection of F and F_2. At outcrop 10 only a slabby jointing is present and its pole is indicated by J.

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