PALEOMAGNETISM OF TOARCIAN HAZELTON GROUP VOLCANIC ROCKS IN THE YEHINIKO LAKE AREA (104G/11, 12): A PRELIMINARY REPORT

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INTRODUCTION

The first paleomagnetic study of Hazelton Group volcanic rocks included three localities in north-central British Columbia, near the eastern margin of the Intermontane Belt (Monger and Irving, 1980). A second, more recent study included two localities near the western margin of the Intermontane Belt and a third near the village of Telkwa (Vandall and Palmer, 1990; Figure 1-18-1). Both studies documented stable normal and reversed polarity magnetizations interpreted to be primary and Early Jurassic. The direction of magnetization at each of the six localities is different. However, within localities the data exhibit internally consistent directions of magnetization and, although declinations vary between each locality from 227° to 359°, inclinations are well grouped about an average of 53° (Vandall and Palmer, 1990). By comparing these results with the expected Early Jurassic direction for North America, inclinations were shown to be concordant. This indicates that rocks of the Early Jurassic Hazelton Group were at much the same latitude relative to the North American craton as they are now (Vandall and Palmer, 1990). In contrast, declinations for the Hazelton Group rocks are distinctly discordant, suggesting that large-scale block rotations about vertical axes have occurred between localities and relative to North America (Figure 1-18-1). One explanation for these block rotations is that they were generated by the process of accretionary tectonics which assembled former, discrete Jurassic island arcs along the ancient North American margin by at least Middle Jurassic time. The size and boundary relationships of these blocks is not yet known, and this information is critical to the assessment of possible rotation mechanisms.

The purpose of this investigation is to extend the geographic coverage of paleomagnetic data to assess the implications of these apparent large-scale block rotations and the apparent lack of latitudinal displacement relative to North America. Recent geochronometry and detailed mapping carried out around the Bowser Basin have advanced the concept that the Hazelton Group represents several volcanic episodes, perhaps related to discrete island arcs (*e.g.*, Anderson and Thorkelson, 1990; Brown and Greig, 1990; Diakow, 1990; MacIntyre *et al.*, 1989). As a consequence, paleomagnetism is ideally suited to provide a quantitative test of paleogeographic reconstructions and of tectonic settings of the Hazelton Group island arcs. In addition, Hazelton Group rocks studied to date exhibit periods of reversed polarity which may be chronologically and stratigraphically constrained in order to improve the current poor record of Early Jurassic magnetic polarity chrons. Establishing polarity zones would provide a powerful tool for stratigraphic correlation in the Hazelton Group.

In this report we outline the initial fieldwork, laboratory procedures in progress, preliminary results and proposed follow-up investigations for 1992.

GEOLOGY AND SAMPLING

The study area lies within northwestern Stikinia, approximately 20 kilometres east of the Coast Belt (Figure 1-18-1). Regionally, the stratigraphic succession includes Paleozoic limestones and island-arc volcanic rocks of the Stikine assemblage, Late Triassic and Early Jurassic island-arc volcanic and volcanogenic rocks of the Stuhini and Hazelton groups, and Late Cretaceous to Tertiary molasse sedimentary rocks of the Sustut Group. The Middle to Late Jurassic Bowser Lake Group is notably absent, due either to nondeposition or to erosion. Late Triassic, Early Jurassic, Middle Jurassic and Eocene plutons intrude all older units.

In the Iskut River area, 100 kilometres to the southeast, Anderson and Thorkelson (1990) divided the Hazelton Group into four formations. The lower three – the volcanogenic-dominated Unuk River, Betty Creek and Mount Dilworth formations – are overlain by the uppermost Salmon River Formation. In the Yehiniko Lake area, the well-exposed gently dipping Toarcian volcanic rocks of interest in this study are believed to be equivalent to the Salmon River Formation. Their late Early Jurassic age (Toarcian; Harland *et al.*, 1989) is well constrained by U-Pb and K-Ar geochronometry, and by macrofossils. A lower age constraint is provided by an andesite flow-breccia collected at locality IV shown in Figure 1-18-2, which yielded a zircon U-Pb age of 185±2 Ma (M.L. Bevier, written communication, 1991). An upper age constraint is provided by the "Saffron pluton" (formerly Yehiniko pluton) which intrudes the volcanic rocks and yields concordant hornblende and biotite K-Ar dates of 162±7 Ma (J. Harakal, written communication, 1990; Localities I and II, Figure 1-18-2). Further, intravolcanic sedimentary rocks contain Toarcian ammonite fragments, belemnites, brachiopods and scarce bivalves (Locality III, Figure 1-18-2; H.W. Tipper, Report J4-89-HWT, 1989).

In August, 1991, part of an exposure of gently northeast-dipping volcanic rocks, that form a section over 350 metres thick, was sampled in a prominent cirque at the headwaters of Kirk Creek (Figure 1-18-2). Access to the Kirk Creek area was by helicopter from Telegraph Creek, 40 kilometres to the north. Seven sites were sampled in the uppermost 80 metres of the section along the north face of the cirque (Plate 1-18-1; Table 1-18-1; Figure 1-18-3). Drilling was confined to the more massive flow units; site lithologies and stratigraphic positions are summarized in Figure 1-18-3 and Table 1-18-1.

The section comprises four divisions: (1) unstudied, lowermost flows and tuffs, (2) aphyric, amygdaloidal basalt flows overlain by mauve volcaniclastic beds, (3) rhyolite, and (4) porphyritic basaltic andesite flows. Division 2 comprises a northeastward-thickening wedge of basalt flows overlain by an equal thickness of epiclastic tuff beds. The flows, up to 5 metres thick, are dark brown to faintly maroon with characteristic abundant and large amygdules. Maroon flow-top breccia and chilled flow-contacts are common. The top half of this division is made up of thin to thick-bedded, poorly sorted and friable lithic-lapilli tuffs, that were not suitable for drilling. Lying on these epiclastic rocks is Division 3, consisting of conspicuous pink to buff-weathering, hematitic flow-banded and flow-folded aphanitic rhyolite (Figure 1-18-3; Plates 1-18-1 and 1-18-2). This

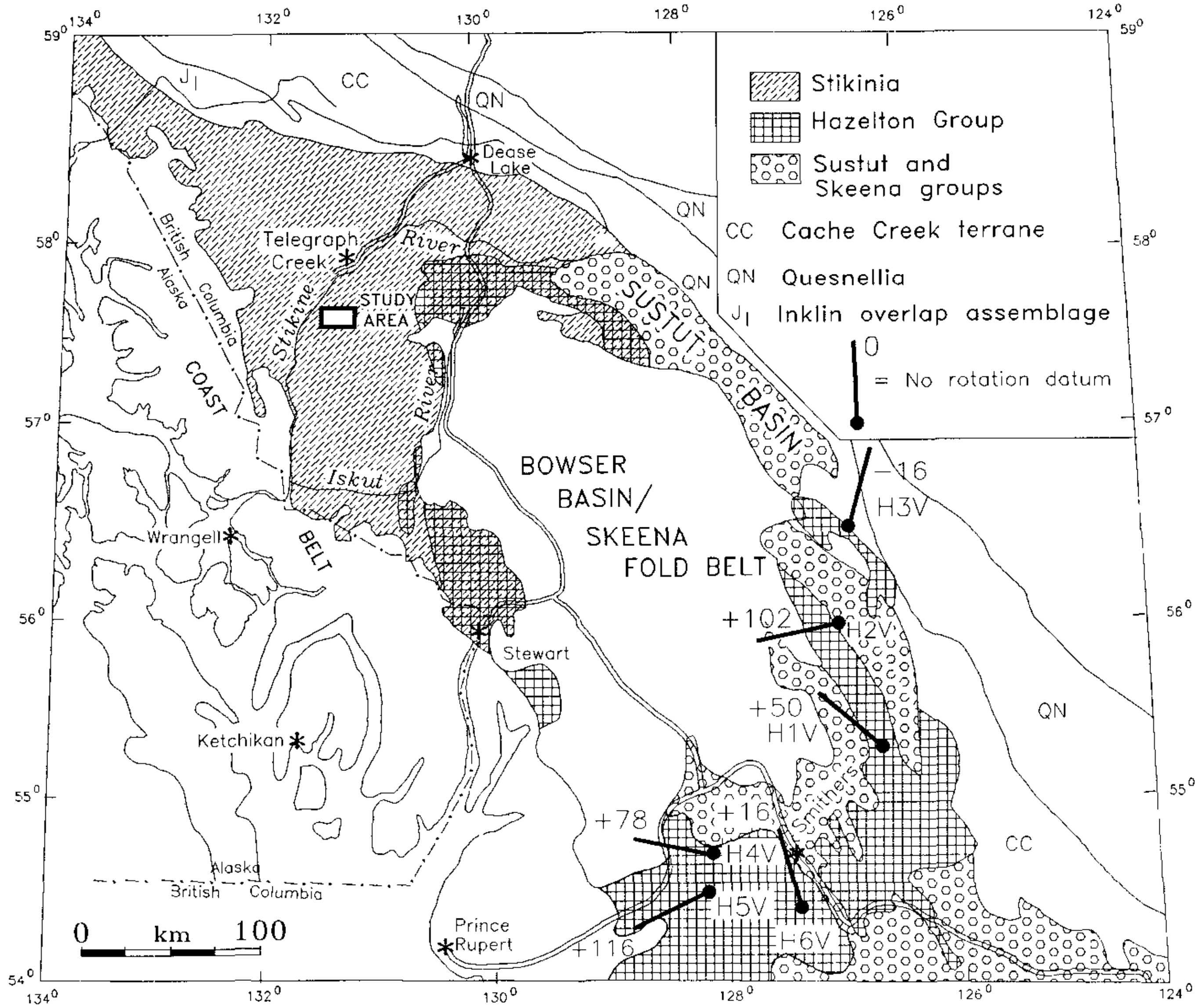

Figure 1-18-1. Regional distribution of Hazelton Group rocks within Stikinia with localities of previous paleomagnetic studies. Localities H1V, H2V, and H3V are from Monger and Irving (1980) and H4V, H5V, and H6V from Vandall and Palmer (1990). Bold lines and corresponding numbers outline the rotation relative to the craton, magnitude in degrees and sense of block rotation since original rock formation (0 or North is the concordant Early Jurassic datum of no relative rotation). Positive (negative) values are counterclockwise (clockwise). Rotation is assumed to be in the smallest angle sense. Block-rotation angles were determined from the observed locality declinations relative to the expected North American reference declination (Vandall, 1990). Geology simplified from Wheeler and McFeely (1987).

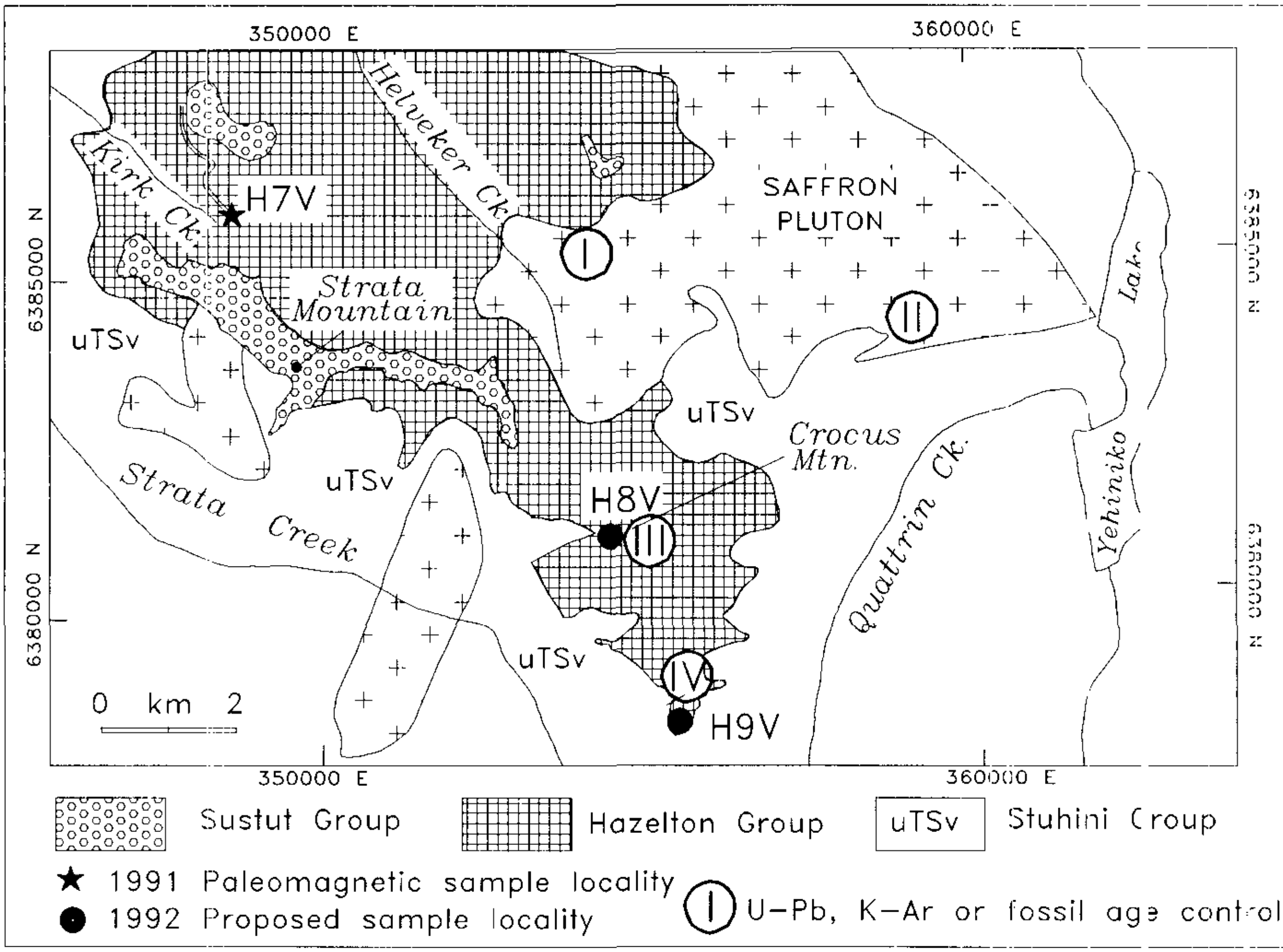

Figure 1-18-2. Simplified geologic setting of the study area with sample locality H7V from this study, and locations H8V and H9V which are targeted for sampling in the 1992 field season. See text for discussion of age control for sites. Geology modified from Brown *et al.* (1990).

TABLE 1-18-1
LOCATION AND LITHOLOGIC DATA FROM THE SEVEN SAMPLING SITES

Site**	Easting	Northing	Elevation	Flow Type
3	348923	6386299	1810 m	Plag.-px. por. andesite
2	348918	6386278	1795 m	Plag.-px. por. andesite
1	348871	6386202	1735 m	Basaltic andesite
5	348631	6386356	1685 m	Amygdaloidal basalt
4	348644	6386319	1670 m	Amygdaloidal basalt
6	348639	6386307	1664 m	Amygdaloidal basalt
7	348657	6386261	1658 m	Amygdaloidal basalt

UTM Zone 09, NAD83.

** Sites are listed in stratigraphic sequence from top to bottom.
Abbreviations: Plag. = plagioclase; por. = prophyritic; px. = pyroxene.

unit can be traced for over 2 kilometres along strike and is an important local marker; samples from the flow are currently being processed for zircon U-Pb dating. Division 4, dark grey plagioclase and coarse pyroxene-porphyritic flows with fractures subparallel to bedding, form the resistant ridge at the top of the section (Plate 1-18-3).

Metamorphic grade in the Kirk Creek area is low. Petrographic and x-ray diffraction data suggest that the volcanic rocks have undergone only zeolite facies metamorphism (Brown and Greig, 1990). In addition, the sample area is distant from the thermal contact aureoles of younger intrusive bodies which could potentially reset the primary magnetization.

Given their well-constrained age, low metamorphic grade and relatively undeformed character, these Toarcian volcanic rocks are ideal targets for paleomagnetic investigation.

METHODS

At each of the seven sites, seven to ten cores were drilled to a depth of about 10 centimetres, of these, only five to six

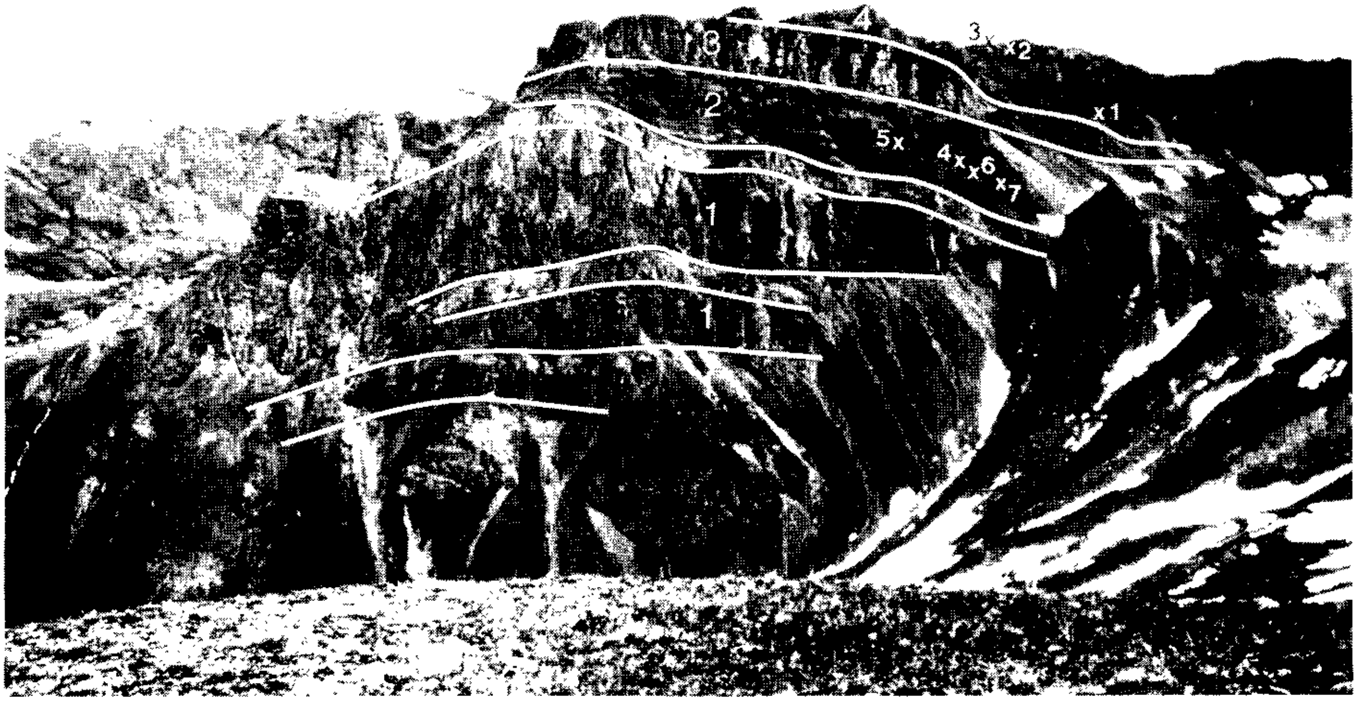

Plate 1-18-1. View to northeast of the Kirk Creek area where the paleomagnetic sites were sampled. The gently northeast-dipping Toarcian flows sampled are the uppermost 80 metres of the section.

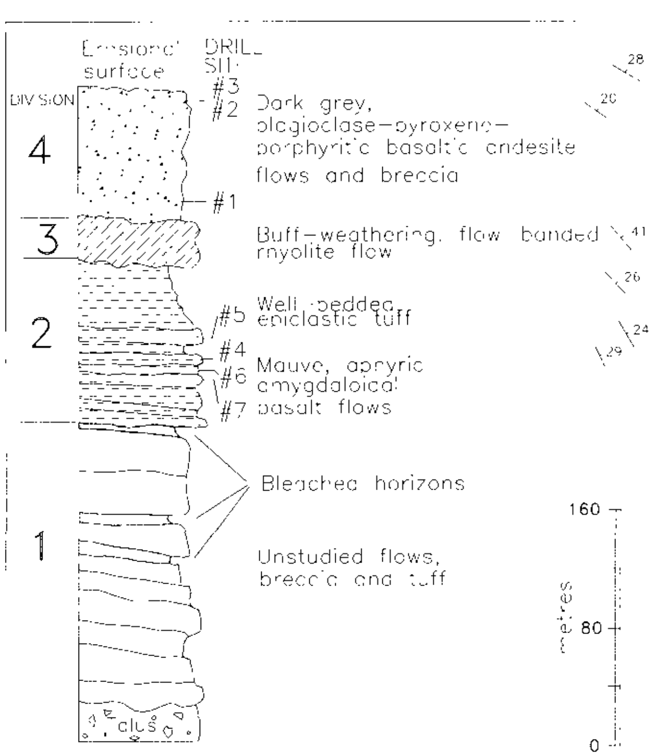

Figure 1-18-3. Schematic stratigraphic column for the Toarcian volcanic rocks in the Kirk Creek cirque, illustrating sample sites.

were recoverable due to the fractured and sometimes friable outcrop. Recoverable cores were oriented *in situ* using both sun and magnetic compasses in order to detect any possible local magnetic distortions; declinations agreed within a few degrees. Basal flow-contact and bedding attitudes were measured at each site. These measurements varied somewhat due to the irregular nature of the flow bottoms, however, the sequence as a whole strikes 300° and dips 20° northeast (Plates 1-18-2 and 1-18-3).

In the laboratory most cores were sliced into two specimens, however, a few provided only a single specimen due to rock fractures. Each specimen's remanent magnetization was analyzed using automated Schonstedt SSM spinner magnetometers, a TSD-1 thermal demagnetizer and an SI-4 static alternating field demagnetizer. In addition, each specimen's anisotropy of magnetic susceptibility (AMS) was measured using an SI-2 magnetic susceptibility instrument. These measurements permit the study of possible flow-induced anisotropies of the magnetic fabric, which may then be related to the measured *in situ* flow attitudes. After initial measurement of the natural remanent magnetization and AMS, each specimen was subjected to alternating field and/or thermal step demagnetization techniques. Specimens were demagnetized at progressively higher discrete alternating magnetic fields and/or temperatures between which their remanent magnetization was remeasured. These experiments isolate discrete components of the natural remanent magnetization in order to permit identification of characteristic stable remanence directions of geologic significance.

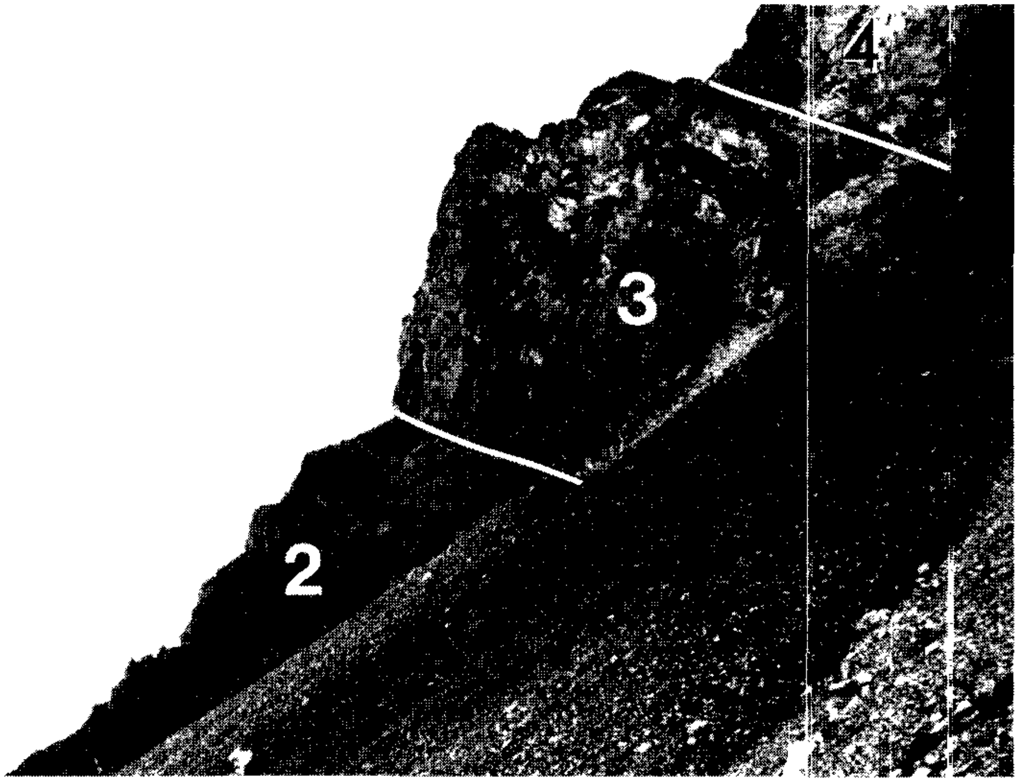

Plate 1-18-2. View to northwest of the gently northeast-dipping epiclastic beds of Division 2, that are directly overlain by the massive-weathering rhyolite flow (Division 3) that was sampled here for U-Pb dating.

Plate 1-18-3. View to southeast of the top of the section (drill site 3), basalt flows are 3 to 5 metres thick with faint and irregular columnar jointing. Erosional surface represents the dip slope.

DISCUSSION

Magnetic susceptibility data indicate that these rocks exhibit a small magnetic anisotropy averaging about 1.3 per cent. The dominant anistropy of magnetic susceptibility ellipsoid is prolate shaped with the axis of maximum magnetic susceptibility oriented near vertical. It is unlikely that this is a flow-induced orientation. More likely it is related to vertical columnar joint like patterns which reflect a history of contraction cooling and a stress regime that could have imparted the weak vertical lineation. Overall, anisotropy is weak and magnetic susceptibilities are large, averaging 17×10^{-3} SI, indicating the suitability of these rocks for paleomagnetic study.

The following discussion is based on step demagnetization analysis on 67 per cent of the collection. Analysis of all specimens subjected to demagnetization techniques indicates that samples from these Toarcian volcanic rocks are stable recorders of the earth's magnetic field. Both normal and reverse polarity magnetizations are present; reverse predominates. During progressive step demagnetization many specimens have a normal magnetic component removed to reveal a higher coercivity and unblocking temperature reversed direction (Figure 1-18-4). In paleomagnetic studies: coercivity is a measure of how strongly held a magnetization is within a rock at the magnetic domain level; (un)blocking temperatures are a measure of the ambient temperature at which a magnetization in a rock is acquired (removed). In all specimens with mixed-polarity magnetizations, the normal component exhibits lower coercivities and unblocking temperatures, and is removed during step demagnetization, yielding a reversed end-point direction. Reversed specimens subjected to thermal step demagnetizations are very stable, exhibiting high, discrete unblocking temperatures in the 550° to 650°C range, indicative of a probable primary magnetization which was acquired during cooling of the lava flows (Figure 1-18-5). In contrast, normal and mixed-polarity specimens subjected to thermal step demagnetization exhibit distributed unblocking temperatures over the entire 200° to 600°C range (Figure 1-18-6). Commonly, the normal component is substantially removed, to yield a hybrid, shallow-dipping, reversed direction (*e.g.*, Figure 1-18-6; demagnetization steps 500° to 550°C). However, in some specimens the normal component is completely removed, isolating the moderately dipping reversed direction (Figure 1-18-4; demagnetization steps 10 to 30 mT). This demonstrates the lower stability magnetic character of the normal polarity magnetization and suggests it is a secondary magnetic overprint. As the natural remanent direction of the normal component in many speci-

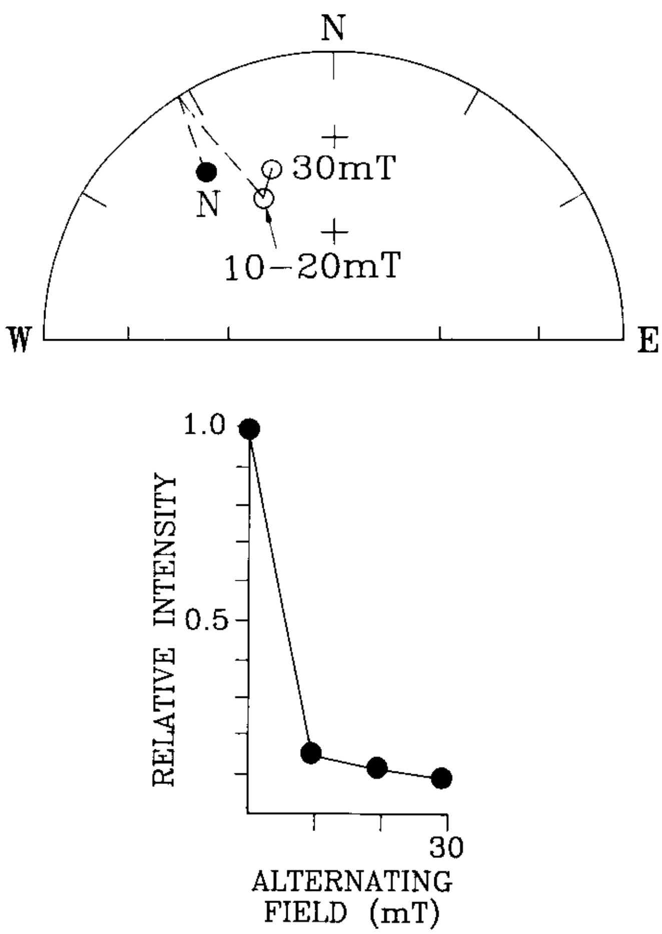

Figure 1-18-4. Example of alternating field demagnetization of a mixed-polarity specimen (Site #2) exhibiting the complete removal of a lower coercivity normal magnetization revealing a stable reversed direction. Direction changes above, intensity changes below. Closed (open) circles represent directions plotted in the lower (upper) hemishere of the equal-area stereonet. N represents the natural remanent magnetization direction (see text). (mT = milliteslas)

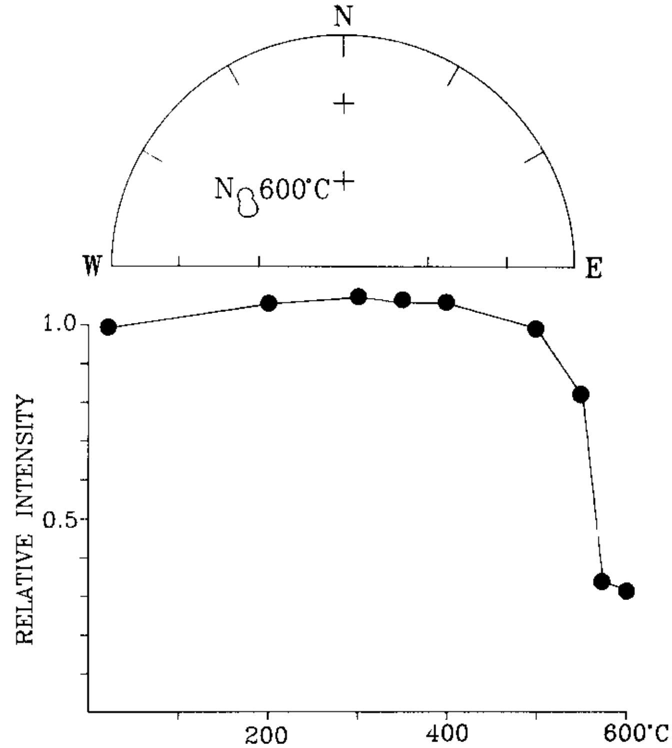

Figure 1-18-5. Example of thermal demagnetization of a high unblocking temperature reverse-polarity specimen (Site #5). Plotting conventions as in Figure 1-18-4.

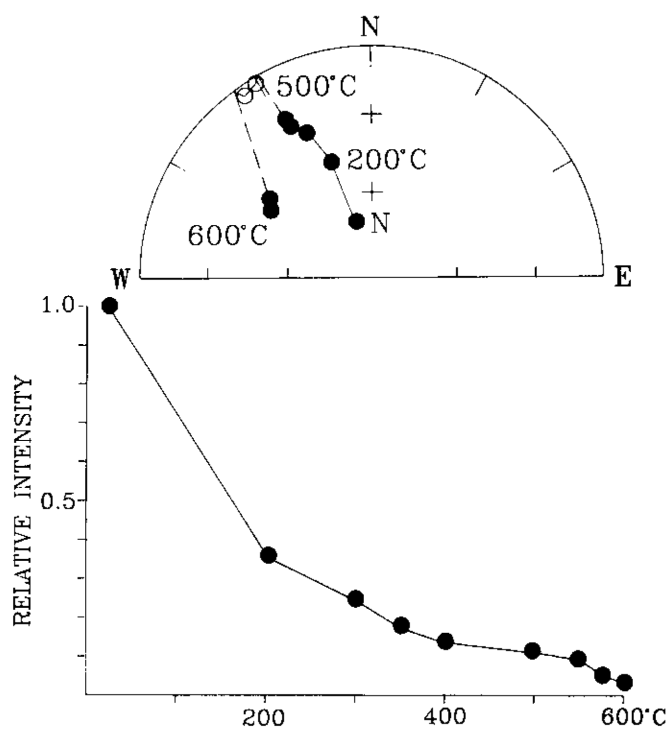

Figure 1-18-6. Example of thermal demagnetization of a mixed-polarity specimen (Site #3) exhibiting distributed unblocking temperatures. Directional changes reflect the removal of the normal magnetization. Natural remanent magnetization direction removed is close to the present earth's magnetic field direction. Plotting conventions as in Figure 1-18-4.

mens is quite steep, close to the present earth's magnetic field direction at this locality, it is probable that the normal component is a recent Brunhes overprint. This interpretation will be tested by future experiments. The uniquely different magnetic characters of the normal and reverse magnetizations are equally well defined by alternating field step demagnetization. Reverse-polarity specimens are very stable, with characteristically high coercivities in excess of 100 milliteslas (Figure 1-18-7). In contrast, normal or mixed-polarity specimens characteristically exhibit large directional changes and lower distributed coercivities (Figure 1-18-8).

Relative to present horizontal, the characteristic reversed magnetization is well grouped and directed north-northwest with an intermediate inclination. Tilt correction for the northeast-dipping attitude of the lava flows moves the north-northwest direction slightly steeper, and to the northwest. By rotating the reversed direction into its antipodal normal polarity position, a direct comparison can be made with the expected Early Jurassic direction [declination 341°, inclination 53° downwards (Figure 1-18-7) calculated using the cratonic reference pole of Vandall and Palmer (1990)]. The inference is that these rocks have undergone a very large rotation, possibly approaching 180° in post-Early Jurassic time. This observation is consistent with the large block rotations previously recognized by Monger and Irving (1980) and Vandall and Palmer (1990). However, these rocks appear to have undergone the largest documented Hazelton Group block rotation.

As the laboratory experiments and final analyses are not yet complete, a more detailed discussion and documentation of the results, and their implications, will be published at a later date.

As it has been demonstrated that these Toarcian volcanic rocks are very good magnetic recorders, additional sampling should be most fruitful. Plans for the 1992 field season include additional sampling in the lower part of the volcanic section in the Kirk Creek area, Crocus Mountain (H8V) and Strata Creek ridge (H9V; Figure 1-18-2). Suitable data from each of these sections would provide important field tests required to assess several outstanding questions. Is the reversed direction pre or post-tilting? Is this reversed polarity chron recognized in each section and can it be accurately dated? What is the consistency of these observations within the Yehiniko Lake area? Can constraints be placed on the size of individually rotated blocks? Can boundaries between rotated blocks be recognized paleomagnetically and geologically? The answers to these questions are critical to our understanding of the accretionary history of the Hazelton Group island arcs and the Intermontane Belt overall.

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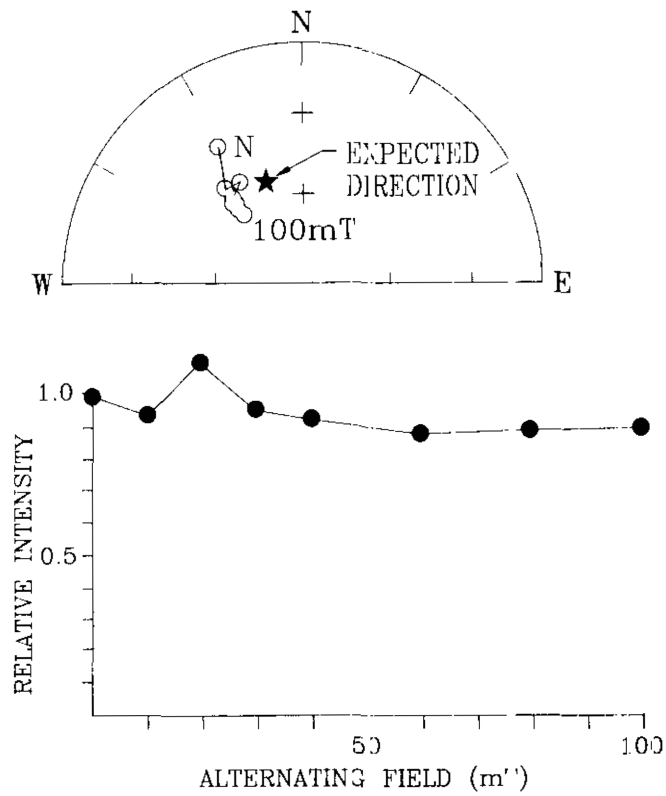

Figure 1-18-7. Example of alternating field (mT = millitesla) demagnetization of a high-coercivity reverse-polarity specimen (Site #4). Plotting conventions as in Figure 1-18-4.

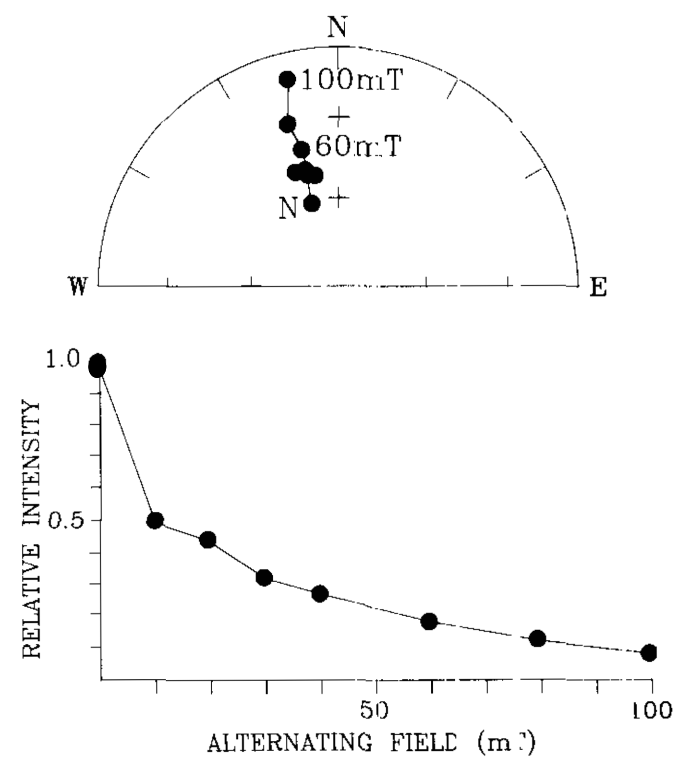

Figure 1-18-8. Example of alternating field demagnetization of a distributed low-coercivity normal-polarity specimen (Site #3). Plotting conventions as in Figure 1-18-4

age data for the area, Brian Sawyer and Linda Bedard (Geological Survey of Canada, Sidney) who provided magnetization diagrams, and Will Tompson (Trans North Helicopters) for his skill and perseverance which was greatly appreciated one windy August evening. Reviews by E. Irving, W.J. McMillan and J.M. Newell significantly improved this manuscript.

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