STRUCTURAL SETTING ALONG THE NORTHWEST FLANK OF FRENCHMAN CAP DOME MONASHEE COMPLEX

(82M/7)

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INTRODUCTION

The Monashee Complex of southeastern British Columiba is one of many metamorphic core complexes in the internal zone of the western Cordillera (see Crittenden, Coney, and Davis, 1980). The Monashee Complex consists of Aphebian basement gneiss and mantling metasedimentary rocks which are exposed in an elongate fenster within Proterozoic to Middle Mesozoic cover sequences of the Selkirk Allochthon (as defined by Read and Brown, 1981; and shown here on Figure 1).

Frenchman Cap dome, the northernmost of four structural culminations with the Monashee Complex, records an extensive history of complex folding, overthrusting (D_1, D_2, and D_3) and late-stage arching (D_3/D_4) believed to be associated with Jurassic to Late Cretaceous/Early Tertiary (?) periods of crustal shortening (Read and Brown, 1981). Superposed on this structural setting is a prominent set of northerly trending fractures, dyke swarms, and normal faults (D_4) related to a regional, more brittle episode of Early Tertiary crustal extension (Price, et al., 1981).

Middle to upper amphibolite facies regional metamorphism is associated with second generation folding in the north-central Frenchman Cap dome (D_2) and is believed to be correlative with Middle Jurassic regional metamorphism developed in structurally overlying rocks of the Selkirk Allochthon (for further discussion, see Read and Wheeler, 1976; Pigage, 1977; Read and Brown, 1981).

Coherent lithostratigraphic successions (Brown and Psutka, 1979; Höy and Brown, 1981) and major structural and tectonic elements (Wheeler, 1965; Höy, 1979; Brown, 1980) have been successfully traced around the northern margin of Frenchman Cap dome from the Columbia River fault zone to the Cottonbelt region north of Ratchford Creek (Figure 2). A similar lithostratigraphic succession has been traced around the southern margin of the dome from the polydeformed Jordan River area (Fyles, 1970; Brown and Psutka, 1979) to the headwaters of Perry River and Myoff Creek (Höy, 1980; Höy and McMillan, 1979; McMillan, 1973). These studies have demonstrated both stratigraphic and structural control on the occurrence of stratiform lead-zinc mineralization within mantling metasediments of Frenchman Cap dome.

The purpose of this study is to complete stratigraphic and structural correlations along the west flank of Frenchman Cap dome as shown on

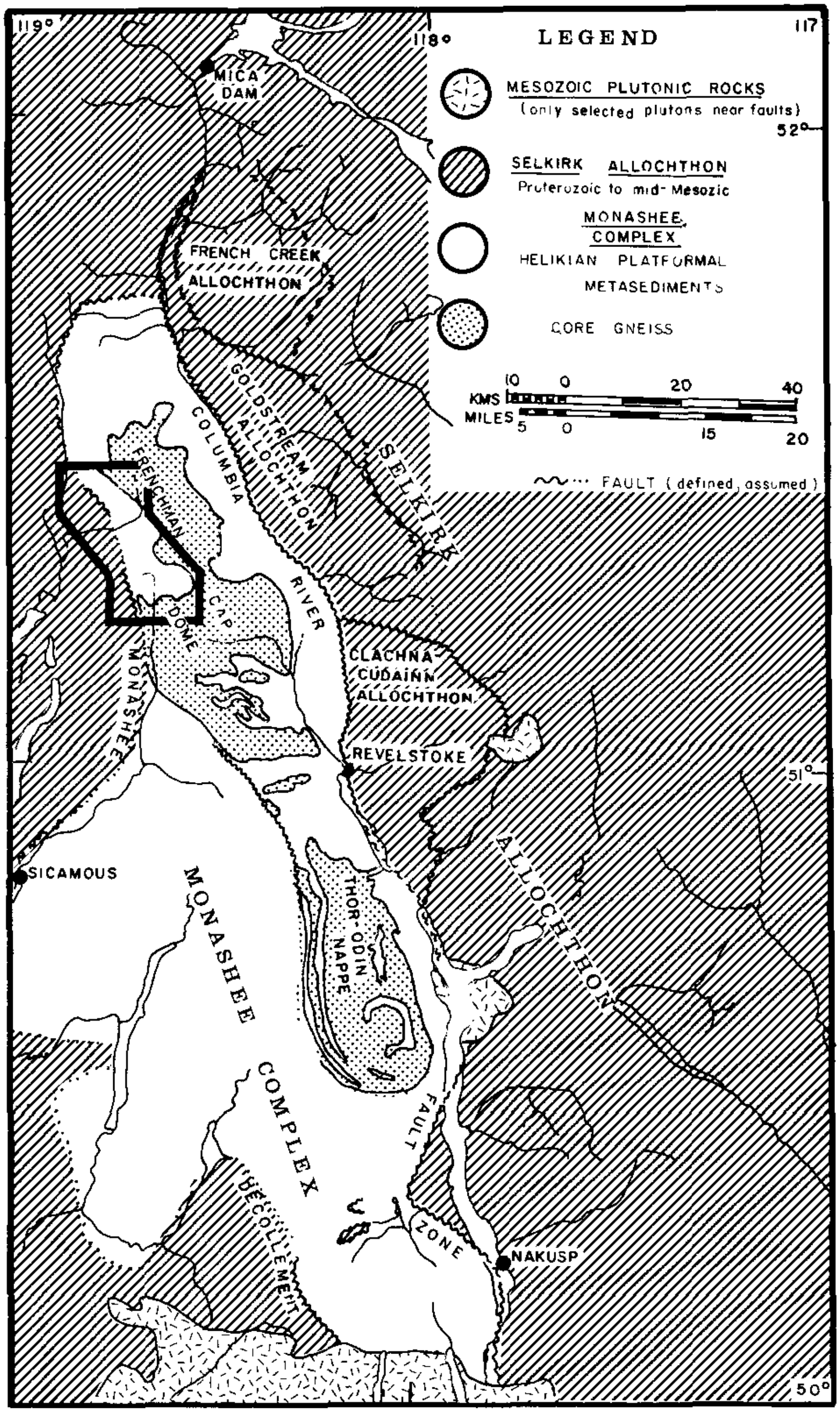

Figure 1. Regional geological map of the north-central Shuswap Complex showing the exposure of basement gneiss and mantling metasedimentary rocks which compose the fault bounded Monashee Complex. The Monashee décollement, which is arched over the culmination of the eastern Shuswap Complex, exposes these Aphebian and Helikian (?) rocks in an elongate fenster within Proterozoic to Lower Mesozoic cover sequences of the Selkirk Allochthon (after Read and Brown, 1971). Location of Figures 3 outlined in black.

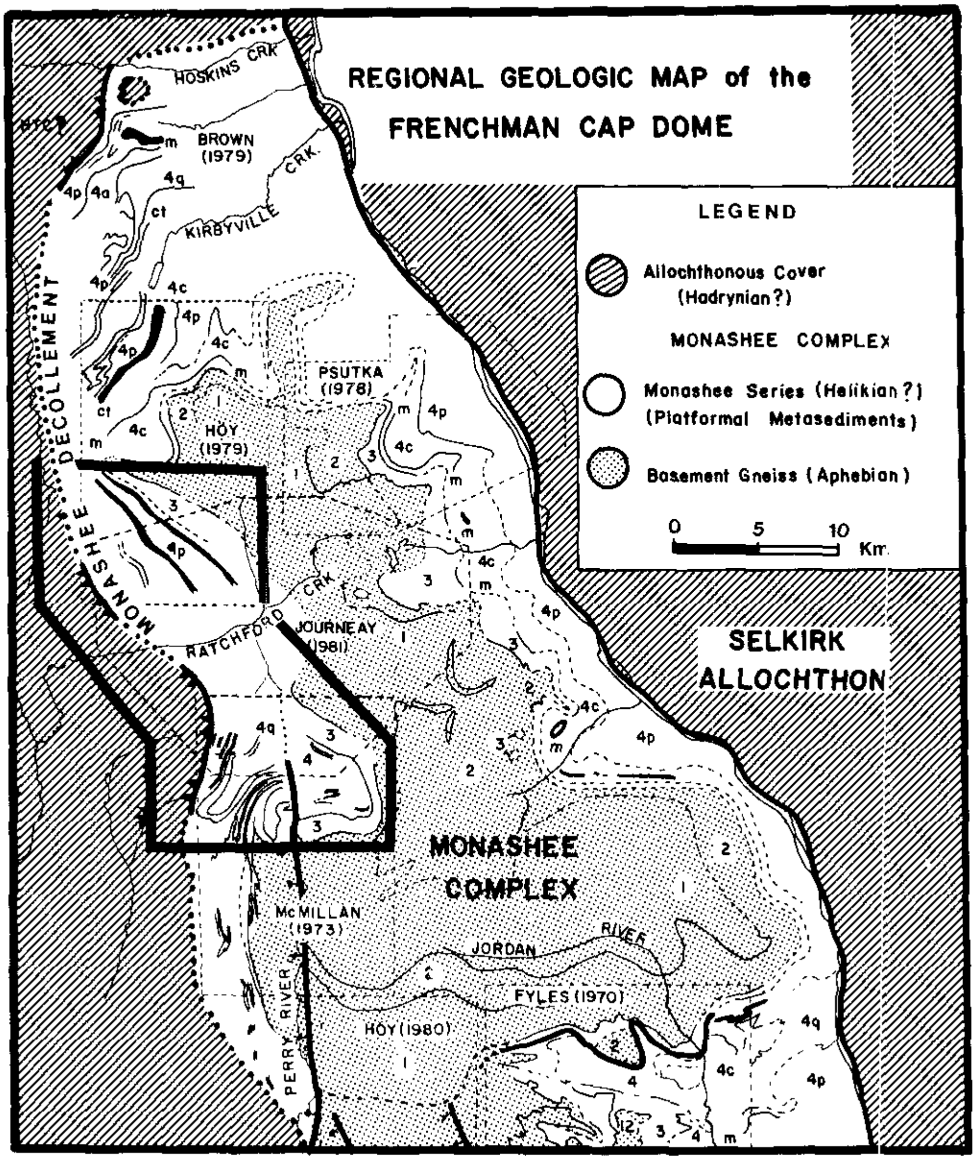

Figure 2. Regional geologic map of the Frenchman Cap dome delineating sources of detailed mapping data, and major lithostratigraphic, structural, and tectonic elements; modified from a recent regional geologic compilation map of the eastern margin of the Shuswap Complex (Höy and Brown, 1981). Map units are referenced on Figure 3. The results of Journeay (this report) are not included for the north-central Frenchman Cap dome.

Figure 2. Specific objectives are: (1) to map the mineralized 'Cottonbelt sequence' from its type locality on Grace Mountain (Höy, 1979) to the headwaters of Perry River; (2) to trace the Kirbyville-Grace Mountain syncline (Wheeler, 1965; Höy, 1979) into refolded structures of the Perry River-Myoff Creek region (McMillan, 1973); (3) to extend mapping of the Monashee décollement (Brown, 1980a, 1980b) as far south as possible; and (4) to present preliminary interpretations of the deformation and structural evolution of the northwest Frenchman Cap dome.

This report is based on the results of detailed mapping in the Cottonbelt (Höy, 1979), Perry River (McMillan, 1973), and Ratchford-Myff Creek regions (Journeay, this study) combined with three-dimensional structural modelling by the author during the 1980/81 seasons (Figure 2). The results of this study are part of an M.Sc. thesis on the structural evolution of the north-central Frenchman Cap dome in progress at Queen's University under the joint supervision of John M. Dixon, Dugald M. Carmichael, and Richard L. Brown (Geotex Consultants Ltd.).

STRATIGRAPHY

Three main lithostratigraphic subdivisions are recognized along the west flank of Frenchman Cap dome (Brown and Psutka, 1979; Höy and McMillan, 1979; Höy and Brown, 1981; and Figures 2 and 3). Exposed in the deepest structural levels of the dome is a sequence of intercalated orthogneiss and paragneiss yielding Rb-Sr whole rock ages of 2.17 Ga (Armstrong and Brown, in prep.). Unconformably overlying this basement complex is a mantling sequence of platform-type metasedimentary rocks locally intruded by a suite of alkalic gneiss tentatively dated at 773 Ma (Okulitch, et al., 1981). These data suggest possible time-stratigraphic correlation of mantling metasediments with the Purcell Supergroup (Okulitch, et al., 1981). The Monashee décollement separates mantling metasediments from an allochthonous sequence of pegmatite-laced feldspathic paragneiss and amphibolite that may be correlative with Hadrynian sequences of the Horsethief Creek Group (Brown, 1980).

APHEBIAN CORE GNEISS

Aphebian core gneiss can be subdivided into lower paragneiss, intermediate orthogneiss, and upper paragneiss in the Ratchford-Bourne Creek region (Journeay, in prep.). The structurally lowest exposed unit (1A) consists of intercalated biotite-quartz-feldspar paragneiss, pelitic and semi-pelitic schist, and quartzofeldspathic gneiss of unknown thickness, and is overlain and locally intruded by alkali-feldspar augen gneiss (1B). Feldspar augen gneiss grades upward into intercalated garnet-hornblende-clinopyroxene gneiss and alaskitic gneiss (1C), banded and migmatitic biotite-hornblende leucogneiss (1D), and homogeneous biotite-quartz-feldspar gneiss (1E). The upper paragneiss (2) unit consists of a heterogeneous sequence of semi-pelitic schist, quartzofeldspathic gneiss, amphibolite, biotite-feldspar augen schist, and some quartzite. Biotite-feldspar augen schist is locally absent due to erosion prior to deposition of overlying autochthonous cover rocks.

AUTOCHTHONOUS COVER (HELIKIAN ?)

Mantling metasedimentary rocks along the west flank of Frenchman Cap dome attain a stratigraphic thickness of nearly 2 kilometres. The succession consists predominantly of quartzite, quartz-mica schist, semi-pelitic and pelitic schist, biotite-quartz-feldspar paragneiss, calc-silicate, and thin but laterally continuous marble horizons. Within this sequence,

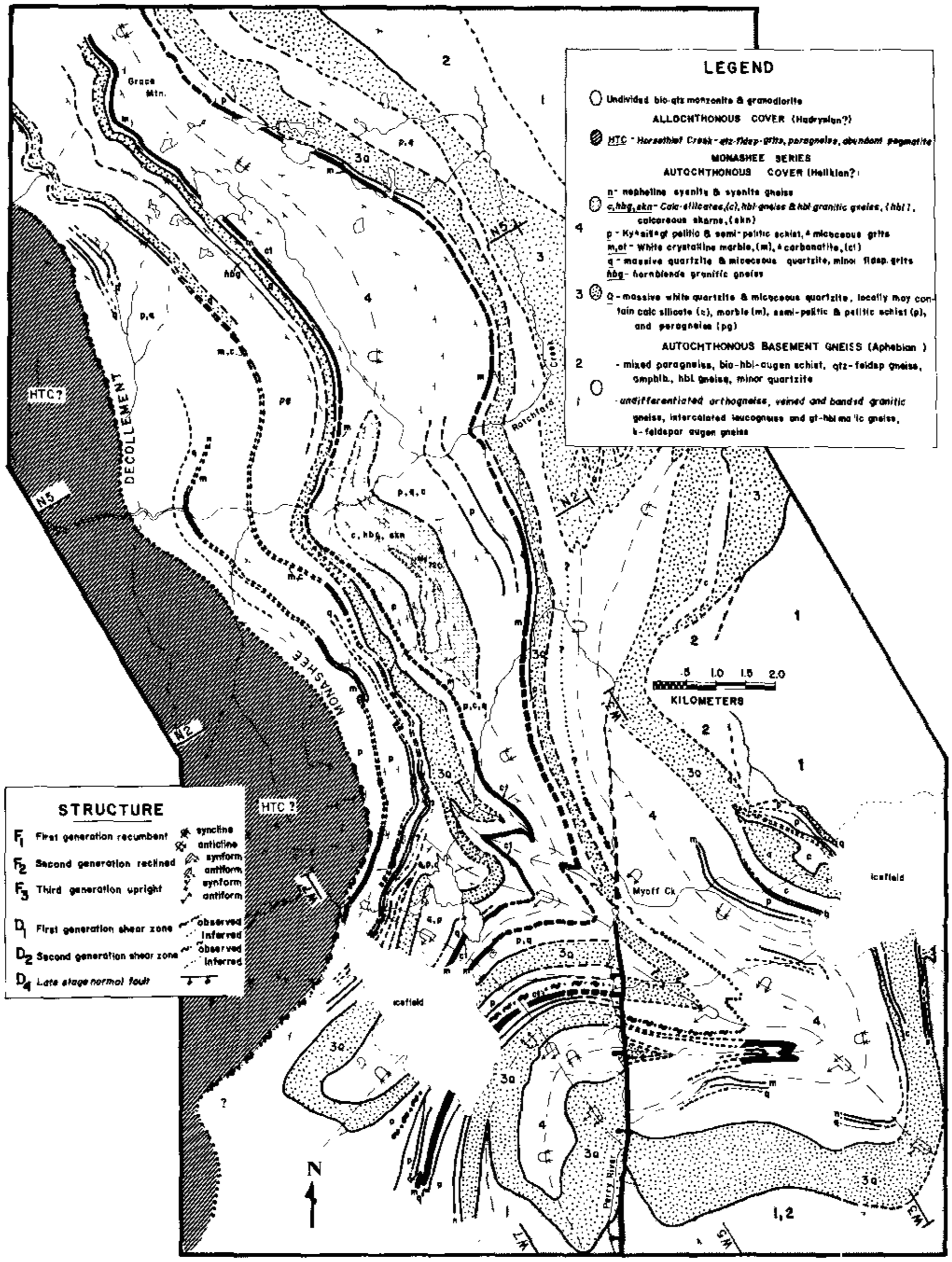

Figure 3. Geologic compilation map of the northwest flank of Frenchman Cap dome; geology after McMillan (1973), Höy (1979), and Journeay (this report). Sources of data are referenced on Figure 2.

basal quartzite (3q) and marble layers (Wheeler, 1965; Fyles, 1970; McMillan, 1973) and locally carbonatite and mineralized layers (McMillan, 1973; Höy, 1979) are used as marker units to delineate major structural elements. Detailed sections of particularly useful marker horizons, and their position in a stratigraphic succession due south of Ratchford Creek, are presented on Figure 4. Locally defined stratigraphic sections in remaining portions of the platform sequence exhibit lateral facies variations that prohibit detailed regional correlation.

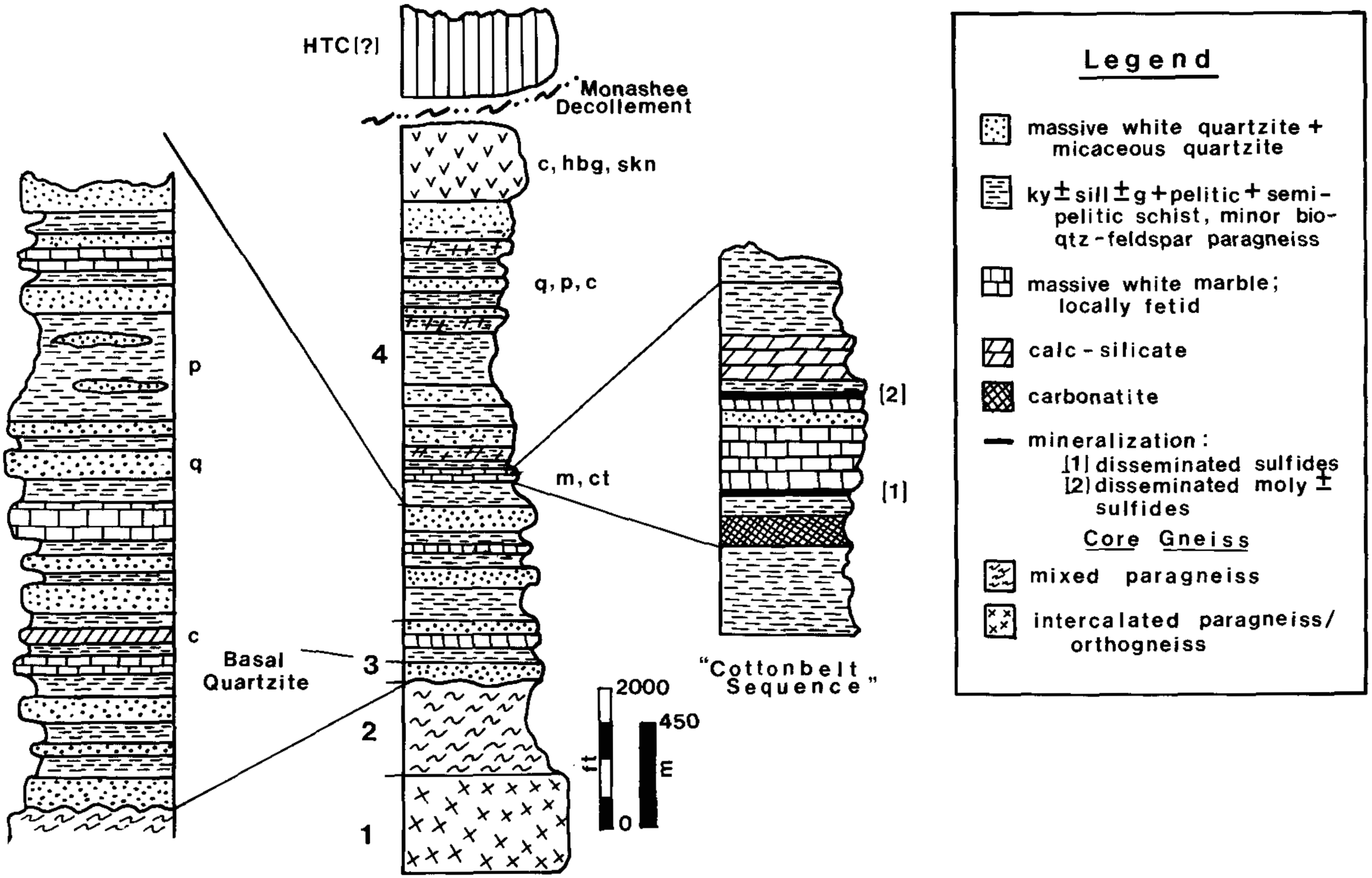

Figure 4. Detailed sections of useful marker horizons, enveloping metasedimentary units, and their stratigraphic position in a lithostratigraphic succession due south of Ratchford Creek. This succession was compiled from stratigraphic sequences on both limbs of the Grace Mountain syncline using marble-carbonatite (4m, ct) and lower quartzitic (3) units as reference horizons. The boundary between map units 3 and 4 is interpreted to be the lower contact of a thick pelitic schist and underlying quartzite unit several hundred metres below the marble-carbonatite marker.

An instructive example of lateral facies changes occurs along the upper limb of the Kirbyville-Grace Mountain syncline between Grace Mountain and Ratchford Creek (Figure 3). Calc-silicate and micaceous schist near Grace Mountain grade laterally into fine-grained biotite-quartz-feldspar paragneiss and biotite schist to the south. It is unlikely that these are structurally induced lithologic variations because of the perseverance of both a marble-carbonatite marker to the east and marble-quartzite horizons to the west. Primary sedimentary structures indicating stratigraphic top directions are poorly preserved in complexly deformed zones throughout the field area. Crossbedding has been locally observed in basal quartzite units above the basement-cover contact and confirms the structural interpretation.

ALLOCHTHONOUS COVER (HADRYNIAN ?)

Allochthonous cover sequences have not yet been mapped in detail but consist primarily of feldspathic grits, amphibolite, hornblende gneiss, micaceous schist, and calc-silicate, abundantly laced with both concordant and discordant pegmatite. This distinctive sequence forms the hanging wall of the Monashee décollement along the west flank of Frenchman Cap dome and is apparently traceable into known exposures of Horsethief Creek Group along the northern margin of the dome (Brown, 1980).

DEFORMATION

Structural analysis in the north-central Frenchman Cap dome has outlined three generations of penetrative deformation that are believed to be associated with Jurassic to Late Cretaceous/Early Tertiary (?) periods of crustal shortening (Read and Brown, 1981). Each generation (D_1, D_2, and D_3) represents a period of progressive deformation which can be recognized in the field by the relationship of minor structures to regional metamorphic mineral assemblages, and by consistent overprinting relationships on both macroscopic and mesoscopic scales. The oldest recognizable structures in the north-central Frenchman Cap dome deform both Aphebian basement gneiss and autochthonous metasedimentary rocks that unconformably overlie them. This suggests that pre-Helikian (?) deformation has either been pervasively overprinted by younger orogenesis or is non-existent. Structures related to all three generations of deformation are superposed and modified by a prominent set of northerly trending fractures, dyke swarms, and normal faults associated with a younger episode (D_4) of regional crustal extension (Price, et al., 1981). A similar hierarchy of deformation is manifest in adjacent parts of Frenchman Cap dome and has been previously described by Wheeler (1965), Fyles (1970), McMillan (1973), Psutka (1978), Brown and Psutka (1978), Höy (1979), Brown (1980a, 1980b), and Read and Klepacki (1981).

Serial cross-sections and sequential deformation diagrams presented in Figures 5 and 6 summarize both the geometry and interpreted structural evolution of the northwest Frenchman Cap dome.

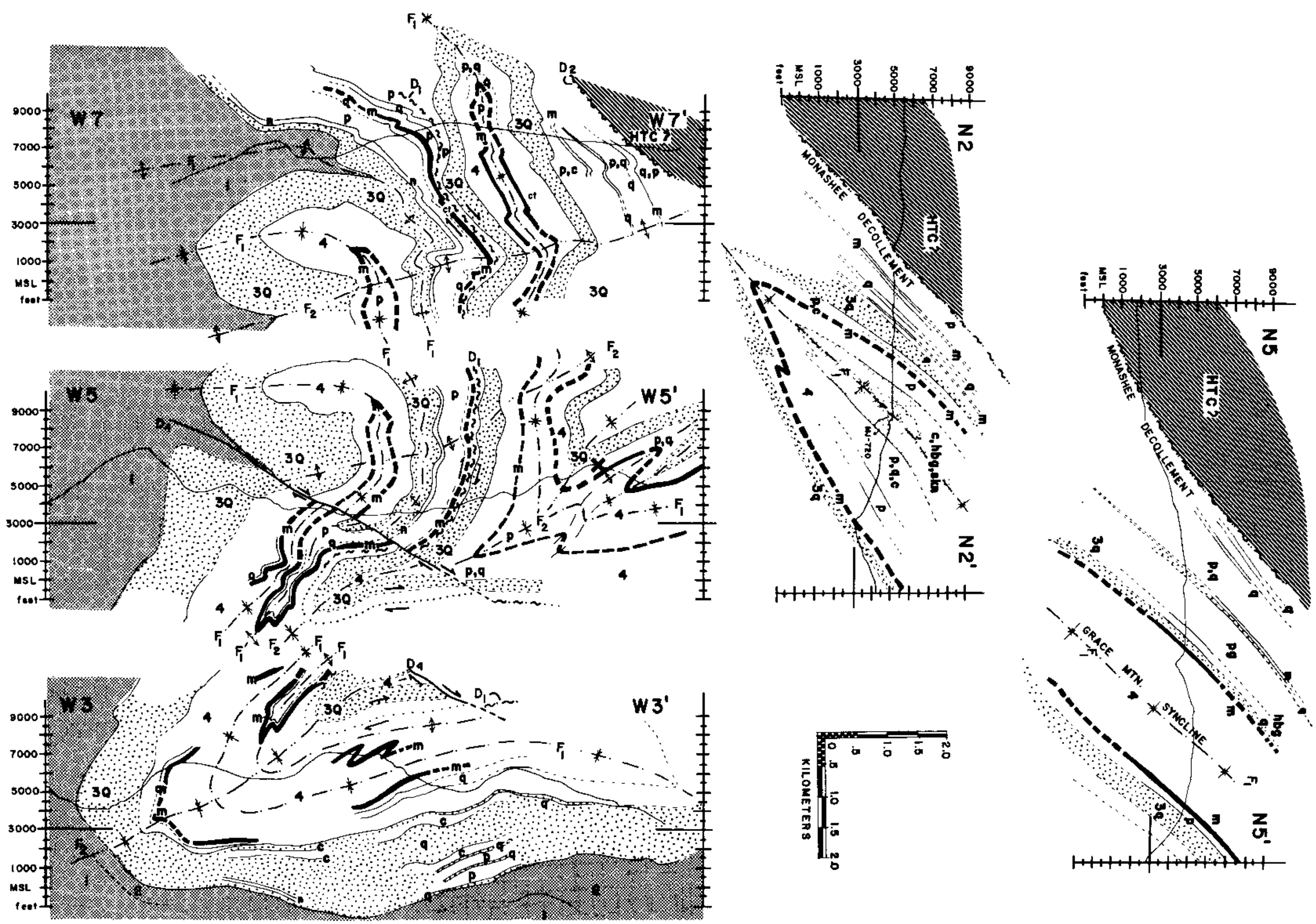

Figure 5. Serial cross-sections through the northwest flank of Frenchman Cap dome. These vertical sections are located on Figure 3 and are based on surface map data (Figure 2) and three-dimensional structural modelling.

D_1 STRUCTURES

First generation megascopic folds are characterized by easterly verging, shallow plunging isoclines that have been variably reoriented by subsequent deformation. Two orders of first generation isoclinal folds are recognized in the field area and can be traced into adjacent parts of the north-central Frenchman Cap dome (Journeay, in prep.).

The Kirbyville-Grace Mountain syncline (Höy, 1979; Brown, 1980) has exposed limb lengths in excess of 7 kilometres and dominates the structural setting of the northwest flank of Frenchman Cap dome (Figures 3 and 5). This structure is defined by stratigraphic facing directions in lower quartzites of unit 3, and by the repetition of a distinctive marble-carbonatite marker in unit 4 (Höy, 1979). The axial surface trace of the Kirbyville-Grace Mountain syncline extends from the southern headwaters of Kirbyville Creek (Hoy, 1979; Brown, 1980a), through the Cottonbelt region (Hoy, 1979), and has been projected south of Ratchford Creek by Höy and McMillan (1979). Both limbs of the Kirbyville-Grace Mountain syncline have now been traced to the west branch headwaters of Myoff Creek and Perry River where they are refolded by macroscopic second generation folds (Figures 3 and 5). The closure of the Kirbyville-Grace Mountain syncline is correlated with the westernmost isoclinal fold closure of McMillan (1973).

Second order, first generation isoclines are well exposed in the hinge of a major second generation fold near the headwaters of Perry River and Myoff Creek (Figures 3 and 5). Basal quartzite of unit 3 delineates a refolded anticline-syncline pair (McMillan, 1973) with limb lengths of 3 to 4 kilometres. These first generation isoclines structurally underlie the southern extension of the Kirbyville-Grace Mountain syncline. Axial surfaces of these second order D_1 structures can be traced around the hinges of major second generation folds in the Perry River-Myoff Creek area (McMillan, 1973; and Figure 5), and extend into the north-central Frenchman Cap dome where they become periclinal in character (Journeay, in prep.). The apparent vergence and limb length of this first generation anticline-syncline pair suggests that it may be either a second order structure on the lower limb of the Kirbyville-Grace Mountain syncline, or related to an episode of D_1 deformation prior to or synchronous with emplacement of the Kirbyville-Grace Mountain syncline (Figure 6).

A homotaxial northwest-facing sequence of lower quartzite (3q), calc-silicate (3c), interlayered pelite-quartzite (4p, q) and marble-carbonatite (4m, ct) is exposed on adjacent limbs of two first generation isoclinal folds near the western headwaters of Perry River (Figure 3). The repetition of this distinctive sequence strongly suggests that the Kirbyville-Grace Mountain syncline may have been displaced northeastward along a low-angle thrust fault relative to underlying D_1 isoclinal folds (Figures 5 and 6). Displacement along this fault clearly pre-dates D_2 deformation and Middle Jurassic regional metamorphism. The lateral extent and timing of this fault with respect to the development of second order D_1 isoclinal folds have not yet been determined.

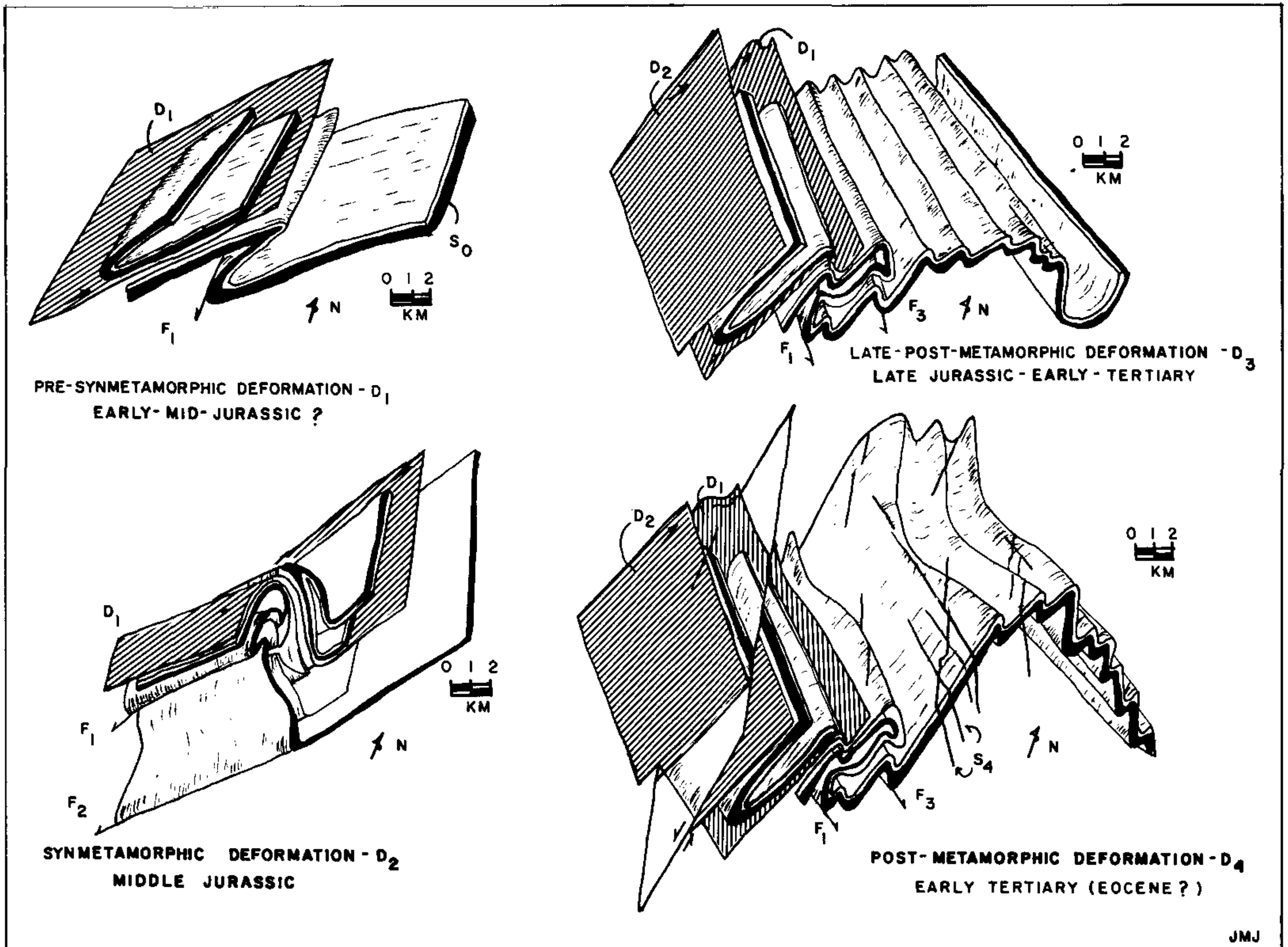

Figure 6. Sequential deformation diagrams illustrating respective generations of deformation and the interpreted structural evolution of the north-central Frenchman Cap dome. The effects of D_2 deformation have been removed for clarity in the representation of post-metamorphic deformation. D_3 and D_4 deformation diagrams refer to structures along an east-west cross-section through the north-central Frenchman Cap dome.

On a mesoscopic scale, first generation folds generally contain an axial planar fabric that is subparallel to compositional layering along attenuated fold limbs. This axial planar fabric is defined by the flattening of quartz and feldspar, and by the preferred orientation of platy metamorphic minerals. This suggests that first generation folds were developed either during initial stages of Early-Middle Jurassic regional metamorphism or an older episode of low-grade metamorphism. The possibility of multi-episodic first generation folding is recognized, but has not yet been documented.

D_2 STRUCTURES

The notable transition from first and second order D_1 isoclinal folds along the northwest flank of Frenchman Cap dome to the complexly refolded structures south of Ratchford Creek reflects the spatial distribution of macroscopic second generation folds below the Monashee décollement. Basal quartzite of the mantling platform sequence (3q) outlines two broad reclined, second generation fold closures which form a distinctive Z-shaped structure adjacent to the headwaters of Perry River and Myoff Creek (Figures 3 and 5). This reclined fold structure (McMillan, 1973) is characterized by west-southwest dipping axial surfaces and west-southwest-plunging fold axes that are subparallel to a prominent southwest-northeast-stretching lineation in all units below the Monashee décollement. A nearly identical fold style is observed on a mesoscopic scale and is well developed throughout the northern Frenchman Cap dome.

Axial surface traces of megascopic D_2 folds are truncated along the western margin of Frenchman Cap dome by the Monashee décollement and associated secondary shear zones. Second order D_2 asymmetric folds can be traced over the culmination of north-central Frenchman Cap dome where they reverse their plunge direction and are overprinted by northerly trending third generation folds (Journeay, in prep.). A very similar set of second generation reclined folds are documented by Read and Klepacki (1981) in the structural depression between Frenchman Cap dome and Thor-Odin nappe.

Consistent overprinting relationships on both macroscopic and mesoscopic scales indicate that D_2 folds were developed during Middle Jurassic syn-metamorphic deformation (Figure 6). This interpretation is supported by the widespread occurrence of medium grade metamorphic minerals such as kyanite and sillimanite that are oriented with their long axes sub-parallel to second generation fold axes and prominent southwest-northeast-stretching lineations.

The Monashee décollement (Brown, 1980a, 1980b; Read and Brown, 1981) is defined along the western margin of Frenchman Cap dome by a wide zone of mylonitized feldspathic grits and semi-pelitic metasedimentary rocks. The fault zone appears to be a major structural discontinuity separating platform-type metasediments in the footwall from rocks that may be correlative with the Horsethief Creek Group in the hangingwall (for further details see Read and Brown, 1981). Preliminary fabric analyses of fault zone mylonites from several alpine localities south of Ratchford Creek suggest an easterly sense of displacement of hangingwall with respect to footwall rocks. This interpretation is based on the asymmetry of minor folds, and the angular relationship of flattening fabrics with respect to mylonitic foliations in the fault zone.

D_3 and D_4 STRUCTURES

Third generation folds are easterly verging, post-metamorphic structures with northwest-trending axial surfaces (Figure 6). In the north-central Frenchman Cap dome, third generation fold axes are refolded by broad, westerly trending open folds that are believed to be associated with subsequent arching events. Along the western margin of Frenchman Cap dome, third generation folds are well developed north of Ratchford Creek but decrease in amplitude and intensity toward the polydeformed Myoff Creek-Perry River region. Fold styles vary from asymmetric kink folds and crenulations in well layered metasedimentary rocks to broad open folds and warps in massive quartzofeldspathic gneiss of the basement complex. This variation in fold style may reflect a competency contrast between a rigid basement and a thinly layered metasedimentary cover that was accentuated during waning stages of regional metamorphism. On a mesoscopic scale, third generation folds crenulate medium grade metamorphic minerals and deform prominent southwest-northeast stretching lineations indicating a late to post-metamorphic age of deformation (believed to be younger than Late Jurassic and older than Eocene).

Late stage arching, which produced the overall domal character of the northern Monashee Complex, apparently post-dates third generation deformation (Figure 6). No minor structures associated with this arching event are recognized in the field area (Figure 3) west of Myoff Creek or the headwaters of Ratchford Creek.

Overprinting all earlier structures in the northern Frenchman Cap dome is a prominent set of northerly trending brittle extension fractures and associated bimodal dyke swarms. These fractures rarely exceed 3 to 5 metres in width and are commonly filled by undeformed lamprophyre dykes and/or granitic pegmatites. Overprinting relationships in one alpine locality indicate that the emplacement of lamprophyre dykes (Eocene ?) post-dates the intrusion of granitic pegmatites.

The Perry River fault (Figures 3 and 5) is the only major normal fault exposed in the field area, and clearly post-dates earlier generations of deformation. Displacement of second generation macroscopic fold axes in the Perry River-Myoff Creek region indicates several hundred metres of relative west-side-down normal movement across the westerly dipping fault surface.

Similar brittle extension features have been described throughout the Frenchman Cap dome (Wheeler, 1965; Fyles, 1970; McMillan, 1973; Psutka, 1978; Brown and Psutka, 1978; Read and Klepacki, 1981) and apparently record a transition from periods of crustal shortening (D_1, D_2, and

D_3) to periods of crustal extension (D_4). The nature of this transition and its tectonic implications for the Early Tertiary evolution of Frenchman Cap dome are not yet fully understood.

MINERALIZATION

A sphalerite-galena-magnetite layer occurs as part of the stratigraphic success ('Cottonbelt sequence') in both limbs of the Kirbyville-Grace Mountain syncline north of Ratchford Creek (Höy, 1979). In tracing this marble-carbonatite-bearing sequence (unit 4m, ct) south of Ratchford Creek, two additional exposures of disseminated oxide-sulphide mineralization were discovered. The first showing occurs on the upper limb of the Kirbyville-Grace Mountain syncline and consists mainly of disseminated molybdenite, pyrite, chalcopyrite, and hematite immediately adjacent to a thin marble unit of the 'Cottonbelt sequence.' This showing is located near the hinge of a first order D_2 fold near the western headwaters of Perry River, and is marked by an 'x' on Figures 3 and 5.

Oxide-sulphide mineralization also occurs in a sequence of calcareous skarns near the hinge zone of the Grace Mountain syncline, approximately 1.75 kilometres south of Ratchford Creek (MJ-720, Figures 3 and 5). Mineralization appears to be zoned and consists primarily of glomeroblastic magnetite, pyrite and minor sphalerite in the centre, and grades outward into disseminated pyrite-molybdenite along its margins.

Assay values for two grab samples within this mineralized zone are presented below.

Sample No.	Au oz./ton ore	Ag oz./ton ore	Pb per cent	Cu per cent	Zn per cent	Mo per cent	WO_3 per cent
MJ-720 A	trace	0.25	0.02	trace	0.04	trace	0.04
MJ-720 B	trace	0.10	0.02	trace	0.03	trace	trace

ACKNOWLEDGMENTS

The author gratefully acknowledges funding from the NSERC (Grant #A-9146) and a grant from the British Columbia Ministry of Energy, Mines and Petroleum Resources awarded to John Dixon of Queen's University. Discussions with Trygve Höy and Bill McMillan (British Columbia Ministry of Energy, Mines and Petroleum Resources) and John M. Dixon and Dugald M. Carmichael (Queen's University) have been very helpful. I would also like to thank Richard L. Brown (Geotex Consultants Ltd. and formerly of Carleton University) for his continuing interest and generous supervision. Hugh Davis, Alain Leclair, Don Murphy, and Carol Newell provided very helpful and inquisitive field assistance for periods of time during the 1980/81 field seasons. In particular, I would like to thank Bryan B. Dean and family of Revelstoke, British Columbia, for their friendship and logistic support.

This manuscript was greatly improved by the thoughtful and constructive criticisms of Bill McMillan, Trygve Höy, Richard L. Brown, and John M. Dixon. Any remaining inconsistencies in the ideas or presentation of this paper are entirely the responsibility of the author.

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