

Geology of the Dufferin Gold Deposit (NTS 11D/16), Halifax County

R. J. Horne and M. Jodrey¹

Introduction

This report describes the geology of the EnviroGold Dufferin gold deposit, currently being operated by EnviroGold Technologies Inc. The deposit is located approximately 8 km north of Port Dufferin (Fig. 1) and occurs in the hinge of the Crown Reserve Anticline (CRA) (Fig. 2a). The CRA represents the faulted extension of the

Dufferin Mines Anticline, where previous mining and exploration occurred, particularly at Dufferin Mines, where reported gold production was 41,801 oz. (Bates, 1987). Previous mining on the CRA included minor development on the south limb of the fold at the Crown Reserve and Maple Leaf mines (Fig. 2a). Extensive exploration, including diamond-drilling by Seabright Resources in the 1980s (Mitchell, 1988), led to the discovery

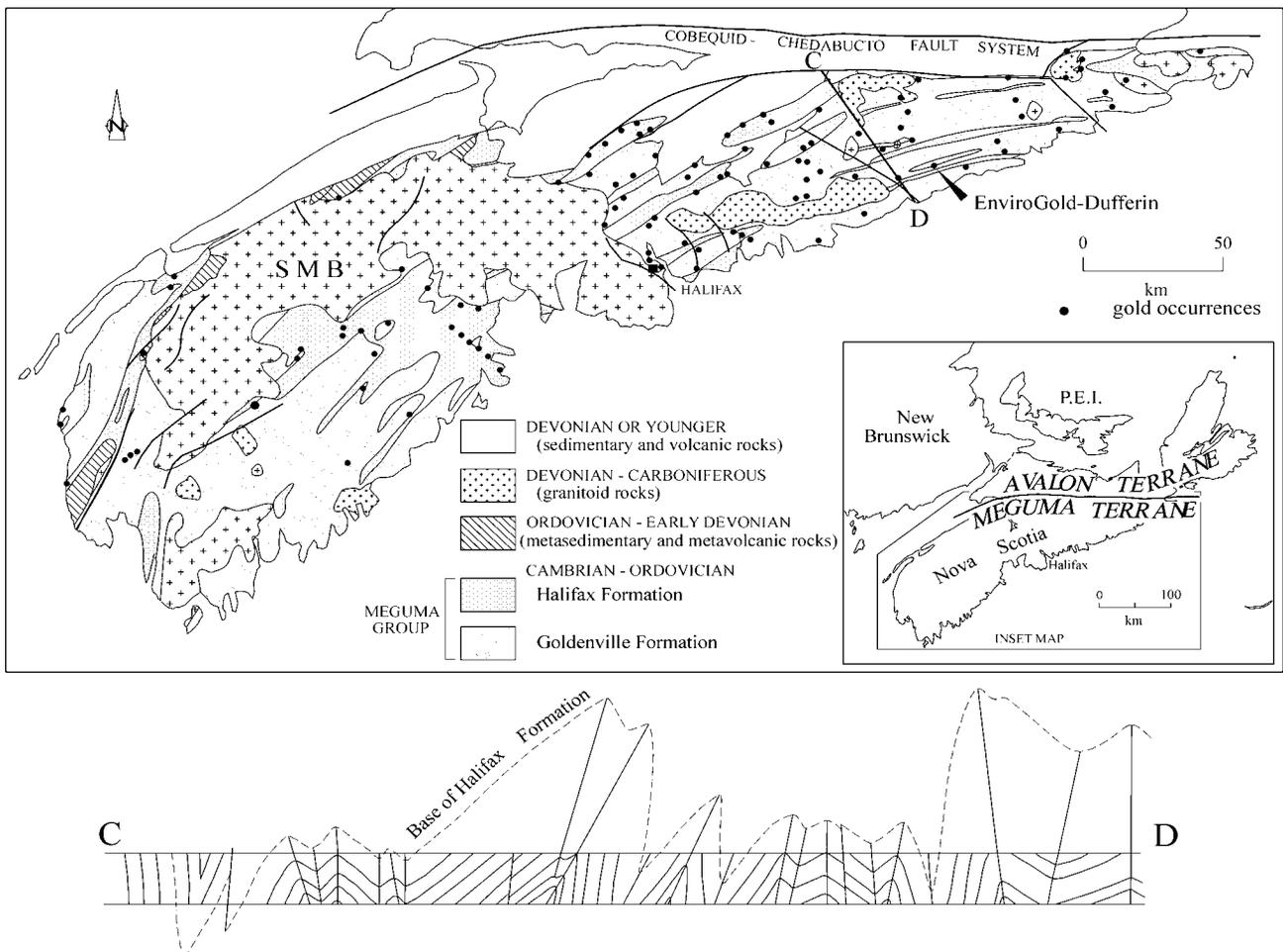


Figure 1. Simplified geological map of the Meguma Terrane showing distribution of gold deposits and the location of the EnviroGold Dufferin deposit.

¹Department of Geology, Acadia University, Wolfville, Nova Scotia B0P 1X0

of auriferous saddle-reef veins in the hinge area of the CRA. During the 1990s Dufferin Resources completed further diamond-drilling which established approximately 700 m strike extension for the upper two saddle-reef veins, and potentially up to 13 saddle-reef zones indicated by a single diamond-drill hole (Jacques Whitford and Associates, 1993; Figs. 2b, c). Current development of the deposit by EnviroGold commenced in late 2000 and as of the end of 2001, mine development has extended to the third saddle-reef vein. The majority of mining has occurred on the second saddle-reef vein (Fig. 2c).

General Geology

Previous work has indicated that the Dufferin Mines and Crown Reserve anticlines represent the south fold of a pair of closely spaced anticlines (Fig. 2a), including the Salmon River Anticline, which define the hinge area of a regional-scale anticlinorium (Dawson, 1899; Malcom, 1929; Mitchell, 1988). The character of the anticlinorium outside the gold mines has not been defined, and is represented by a single anticline trace on regional maps (Faribault, 1897; Henderson, 1986). Within the Dufferin Mines deposit (Fig. 2a) the Salmon River Anticline is described as more open than the Dufferin Mines Anticline, and the saddle vein system is apparently restricted to the southern fold (Dawson, 1899).

The Crown Reserve Anticline defines a tight (interlimb angle of $\sim 47^\circ$; Fig. 2b) chevron-style fold which is steeply inclined to the south (Figs. 2b). The hinge zone of the fold typically defines a rounded arc-shaped structure approximately 5-10 m across and the limbs are uniform and straight. Variations noted in the hinge zone include local flat segments and minor M-folds, where the flat segment has been folded into an open syncline. A well-developed axial planar cleavage occurs, consisting of a spaced (pressure solution) cleavage in metasandstone and a fine continuous cleavage in metasiltstone and slate. There is strong cleavage refraction, from a convergent pattern in metasandstone, with bedding-cleavage angles of $\sim 50^\circ$, to a divergent pattern in metasiltstone and slate, where cleavage is commonly subparallel to bedding.

Stratigraphy within the deposit consists predominantly of medium- to thickly-bedded metasandstone with lesser metasiltstone and slate (e.g. Fig. 3). A typical sedimentary sequence defines a fining-upward cycle of thick, massive metasandstone, gradationally overlain by laminated metasiltstone, in turn overlain by black slate. An average cycle includes approximately 1 m of metasandstone, 5-10 cm of metasiltstone, and 1-2 cm of slate. Some cycles are almost exclusively metasandstone, with < 1 cm of slate, whereas other cycles include over 1 m of metasiltstone and slate.

The northwest-trending Harrigan Cove Fault offsets the regional fold and vein system, with approximately 1.5 km of sinistral strike-slip separation (Fig. 2a). In addition, a significant amount of dip-slip displacement is suggested by the variance in separation of the trace of the Salmon River Anticline and the Dufferin Mines Anticline west of the fault and the Salmon River and Crown Reserve anticlines east of the fault (Fig. 2a). Three significant faults offset the Crown Reserve Anticline, and vein array, within the developed portion of the deposit. These faults are herein referred to, from west to east, as faults 1, 2 and 3 (Fig. 2c). Faults 1 and 3 trend northwest, parallel to the Harrigan Cove Fault, whereas fault 2 runs north-south. All three faults display oblique movement, with sinistral, east-side-down displacement. The dip-slip displacement is less than the strike-slip displacement (compare plan and longitudinal sections, Fig. 2c.).

Structure and Vein Array

Introduction

As will be described in detail below, the auriferous vein array at the EnviroGold Dufferin gold deposit occupies mainly structures related to flexural folding: bedding-parallel shear, and hinge zone dilation. These veins can be grouped into (1) saddle-reef veins, generally defining thickened stratabound veins in the fold hinge, and (2) leg-reef veins, which represent the down-limb extension of saddle-reef veins (Fig. 4). In addition, there are numerous discordant veins, most of which are interpreted to be related to saddle- and leg-reefs. The vein system is generally similar to those

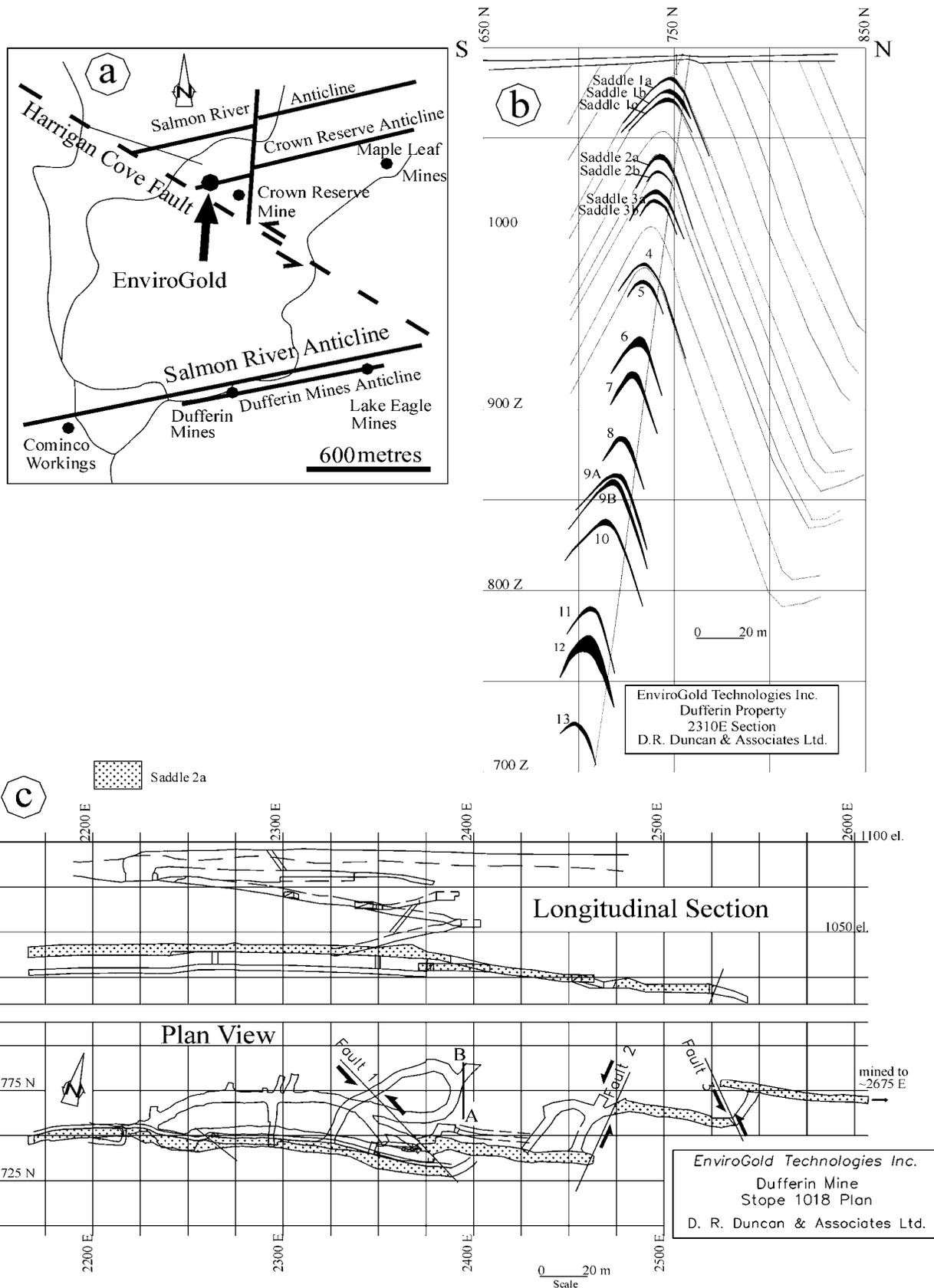


Figure 2. (a) Simplified geology map of the area of the Dufferin Mines and Crown Reserve anticlines, showing the location of previous mines and the EnviroGold Dufferin deposit. (b) Cross-section of the Crown Reserve anticline showing the occurrence of thirteen saddle-reef zones defined by drilling. (c) Plan view and longitudinal section of workings at the EnviroGold Dufferin deposit. The stoped area of saddle-reef 2a is indicated by the cross pattern.

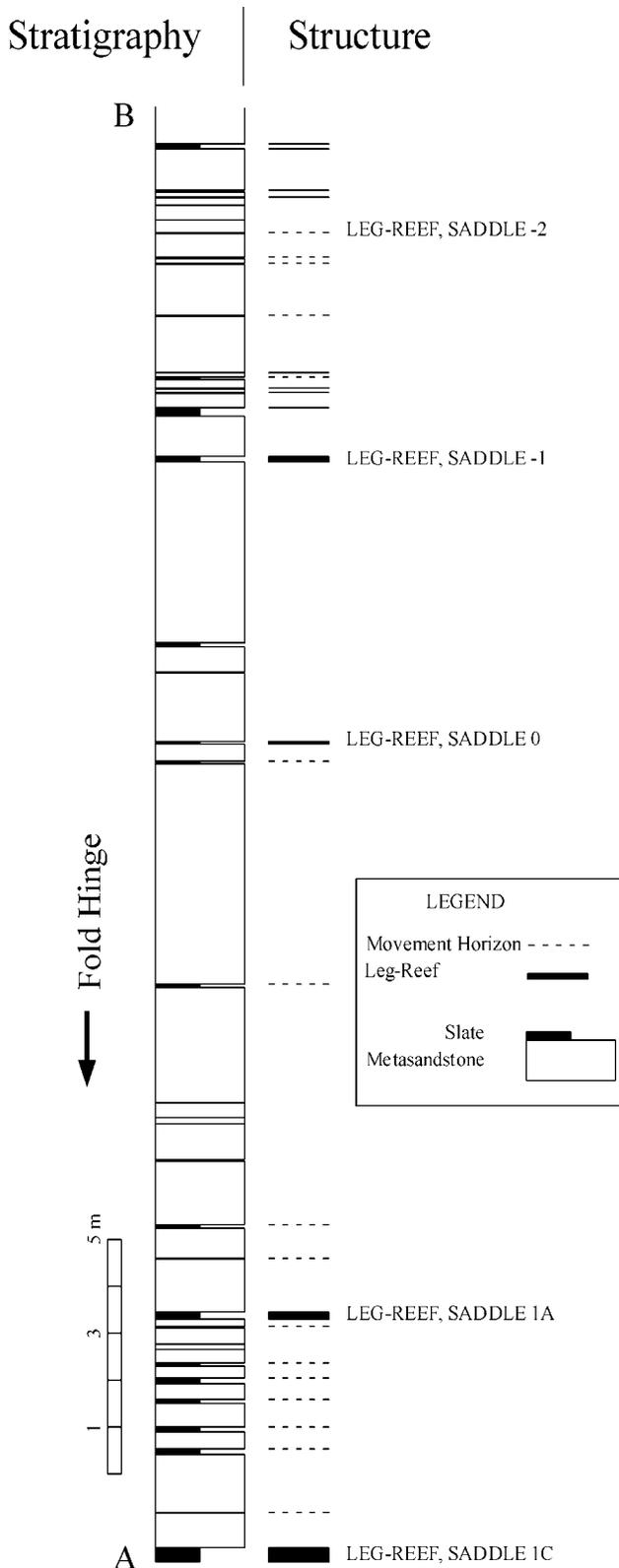


Figure 3. Stratigraphic-structural log of a section (A-B) of the north limb of the Crown Reserve Anticline exposed in the development ramp (see Figs. 2c and 5a for location). Flexural shear structures occur within most slate intervals, with movement horizons occurring at the top of slate beds.

documented in Central Victoria, Australia (e.g. Chace, 1949; Saniford and Kaeys, 1986; Ramsay *et al.*, 1998).

Flexural Shear Structures

Flexural folding is the dominant fold mechanism in the development of chevron-style folds in layered sequences, and results in bedding-parallel shear perpendicular to the fold hinge, where the structurally higher beds move toward the hinge (Fig. 4) (Ramsay, 1974; Tanner, 1989). Flexural shear strain is localized within the incompetent slate layers, where various minor structures are developed, whereas strain within competent layers is minimal (Ramsay, 1974). Abundant evidence of bedding-parallel shear related to flexural folding occurs within the deposit, recorded by minor structures within slate intervals, such as laminated bedding-parallel veins, en echelon shear veins, and movement horizons.

Movement Horizons

Movement horizons are bedding-parallel slip planes reflecting flexural slip. Movement horizons typically consist of thin zones of fault gouge (clay) developed within slate horizons, generally at the contact with overlying metasandstone beds (e.g. Figs. 3, 5b, 6b). The gouge is locally laminated and ranges from <1 mm to ~2 cm thick. The thicker gouge zones locally host angular clasts, including quartz vein material. Striations are developed in the soft gouge, trending roughly perpendicular to the fold hinge. Movement horizons typically occur at all slate-metasandstone boundaries and commonly occur mixed with other flexural-folding structures, such as laminated veins. Movement horizons locally occur at the same stratigraphic horizon on both limbs of the fold, and locally can be traced across the hinge zone (e.g. a movement horizon occurs at the hanging wall margin of saddle 1a across the hinge zone; Fig. 5).

Laminated Veins

Bedding-parallel laminated quartz veins occur within slate beds at several horizons, and represent the leg-reef extensions of some saddle-reef veins (e.g. Fig. 5a, d). The origin of

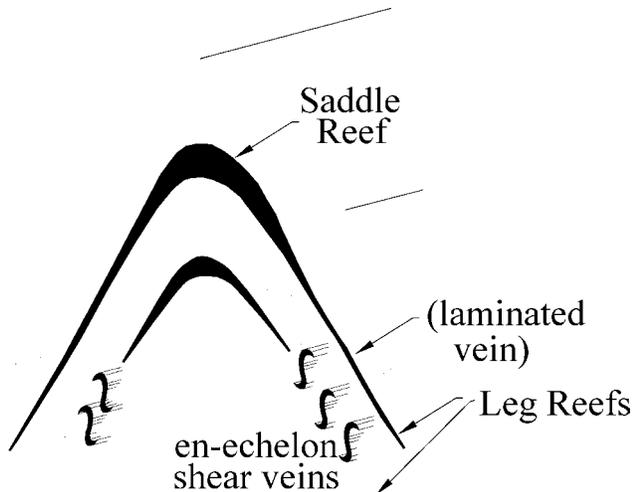


Figure 4. Sketch of a simplified fold showing location of saddle- and leg-reefs, the latter including laminated veins and zones of en echelon veins.

laminated veins within Meguma gold deposits, and elsewhere, has been the subject of much discussion (e.g. Chace, 1949; Henderson *et al.*, 1986, 1990; Tanner, 1989; Jessell *et al.*, 1995; Fowler, 1996). Our preliminary interpretation of laminated veins in the EnviroGold Dufferin gold deposit is that they represent incremental vein growth along bedding-parallel flexural-slip movement horizons. We base this on the following observations: (1) laminated veins represent leg reefs and, therefore, occur along horizons where high shear strains were required; (2) movement horizons occur within slate immediately adjacent to the veins; (3) striations occur on the surfaces between laminations within the vein. These striations are generally perpendicular to the fold hinge, although they vary between laminations, consistent with variations in slip vector between periods of vein growth. Movement horizons and striations could post-date vein formation; however, later slip would be expected to result in parallel striations on all laminations. A replacement origin for laminated veins has been proposed for the central Victoria deposits by Chace (1949), who interpreted the laminations to represent the vestiges of sheared slate, including slickensides, along bedding-parallel faults. We agree that replacement may contribute to vein formation, noting the important concept is that vein emplacement occurred along active bedding-parallel movement horizons.

En Echelon Veins

En echelon shear vein arrays are common in slate or metasilstone beds throughout the deposit, in many instances representing the down-limb extension of saddle-reef veins (i.e. leg-reefs; Fig. 5b and 6b, d, g). The formation of en echelon veins on the limbs of flexural folds is common (Fig. 7a) and such veins have been described in the Meguma Group (Henderson *et al.*, 1986). Veins initiated as extensional “gash” veins at low limb dips are rotated during progressive shear, initially shortened forming sigmoidal shapes, and later extended resulting in boudinage of the veins (Figs. 7a, b). The ends of en echelon veins are “pegged” within metasandstone beds on both sides of host slate intervals. These pegs preserve the original geometric relationship with bedding, allowing for determination of the amount of shear strain recorded within the slate interval since vein formation (Fig. 7c). En echelon veins in the Dufferin deposit all record a high degree of shear (shear strains of 2-3 γ are common), and several display shear-related boudinage (e.g. Figs. 6d, e, g). Locally, some veins show multiple generations of vein development. A reverse sense of shear is indicated for all en echelon shear veins, changing systematically across the fold hinge, and the vein-bedding intersection is parallel to the fold hinge (Fig. 4), consistent with flexural shear perpendicular to the fold hinge. These observations clearly demonstrate a syn-folding origin for these veins.

Saddle-reef Vein System

As outlined above, the vein system is dominated by saddle-reef veins and associated leg-reef veins. Thirteen saddle-reef zones, some consisting of two or three closely spaced saddle-reef veins, have been encountered in diamond-drilling (Fig. 2b), and potential for more exists at depth. Three saddle-reef structures have been developed to date, each of which is distinct in its geometry and makeup.

Saddle-reef 1

Saddle-reef 1 includes three individual saddle-reef veins with associated leg-reefs, referred to, from

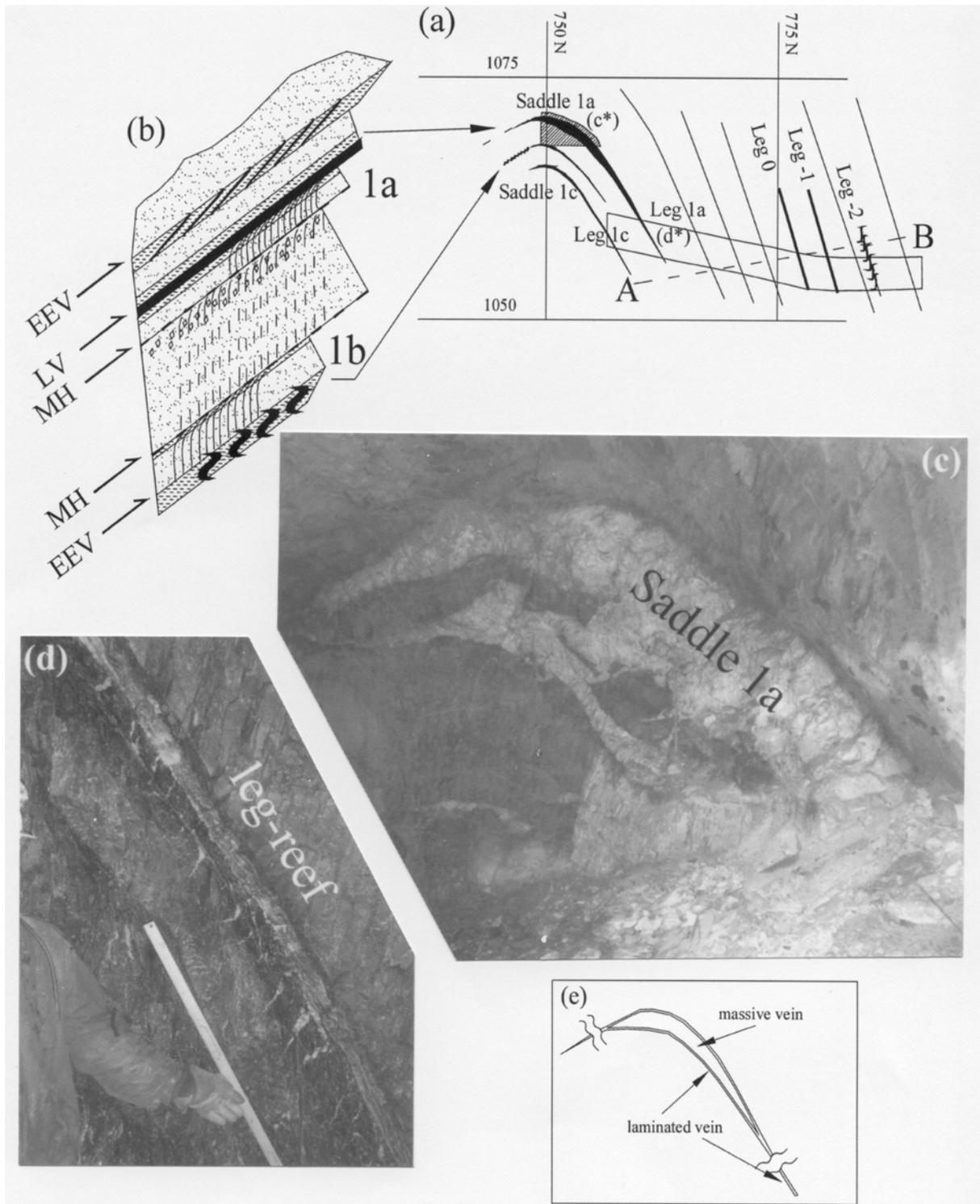


Figure 5. (a) Section at 2400 E showing fold geometry and distribution of saddle-reefs 1a-c and leg-reefs of stratigraphically higher saddle-reefs (Legs 0, -1, -2). Letters with * (e.g. c*) indicate the location of corresponding photograph. (b) Enlargement of a stratigraphic interval of the south limb, including saddle-reef 1a and 1b. Flexural shear structures within slate intervals include en echelon veins (EEV), movement horizons (MH), and laminated veins (LV). (c) Photograph of saddle-reef 1a showing the highly asymmetric geometry; see (b) for location. (d) Photograph of the leg-reef of saddle-reef 1a on the north limb. The leg consists of mainly laminated veins with en echelon veins formed in foot wall slate. Movement horizons are common within the slate with some minor displacement of en echelon veins is recorded; see (b) for location. (e) Schematic diagram of saddle-reef 1a showing the general distribution of massive and laminated veins within the saddle- and leg-reefs.

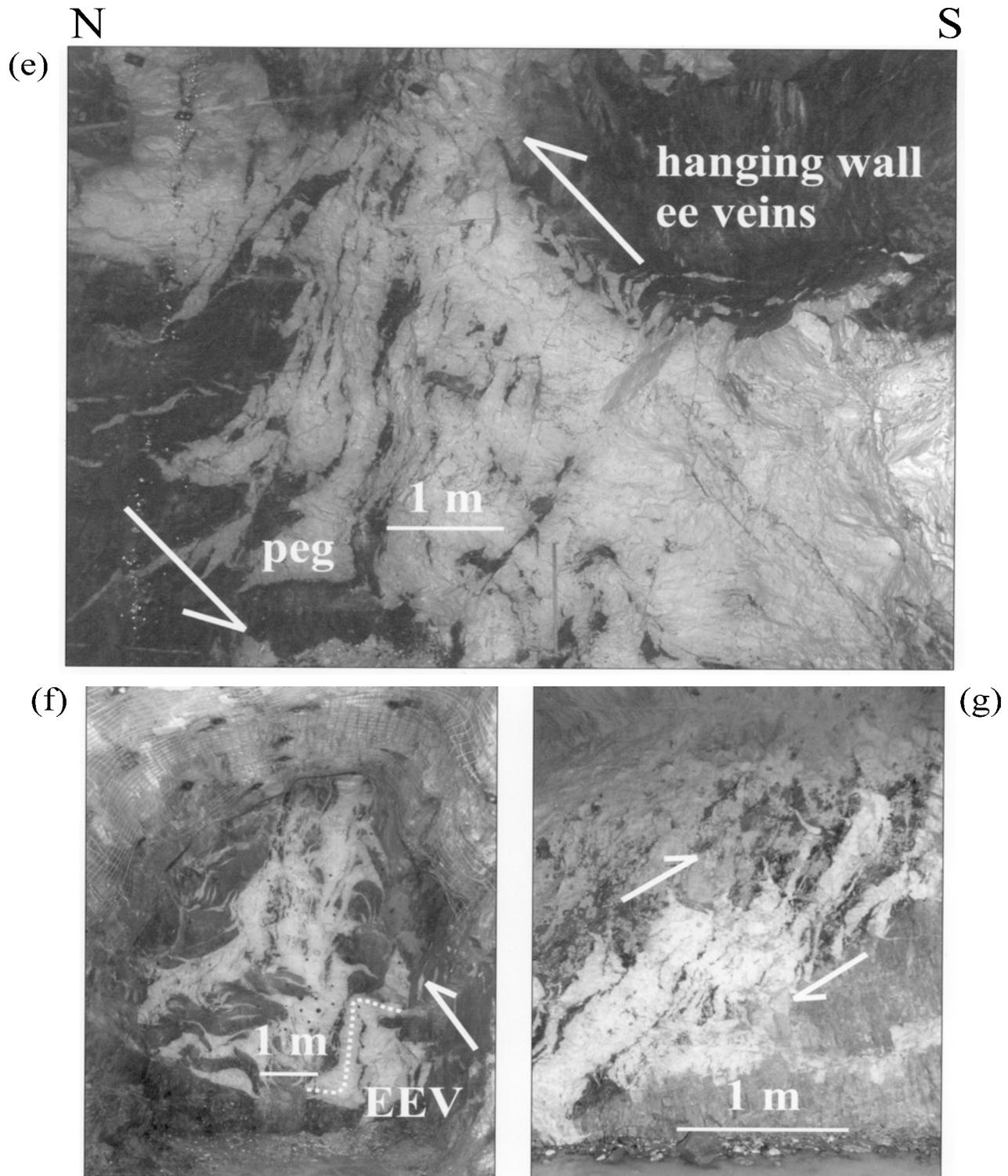


Figure 6. (cont'd) (e) Photograph of saddle-reef 2a at 2380 E. The saddle-reef at this location consists principally of large amalgamated en echelon veins separated by septa of slate on the north part of the hinge. Vein geometry is consistent with flexural shear on the north limb. Note the zone of small en echelon veins in the hanging wall of the north limb showing a similar sense of shear. (f) Photograph of saddle-reef 2a at 2600 E. The saddle-reef at this location is complex, but includes large en echelon veins (EEV) on the north side; dotted line traces the sigmoidal form of an en echelon vein. (g) Photograph of the south leg-reef of saddle-reef 2b, which consists of closely amalgamated, strongly sheared en echelon veins.

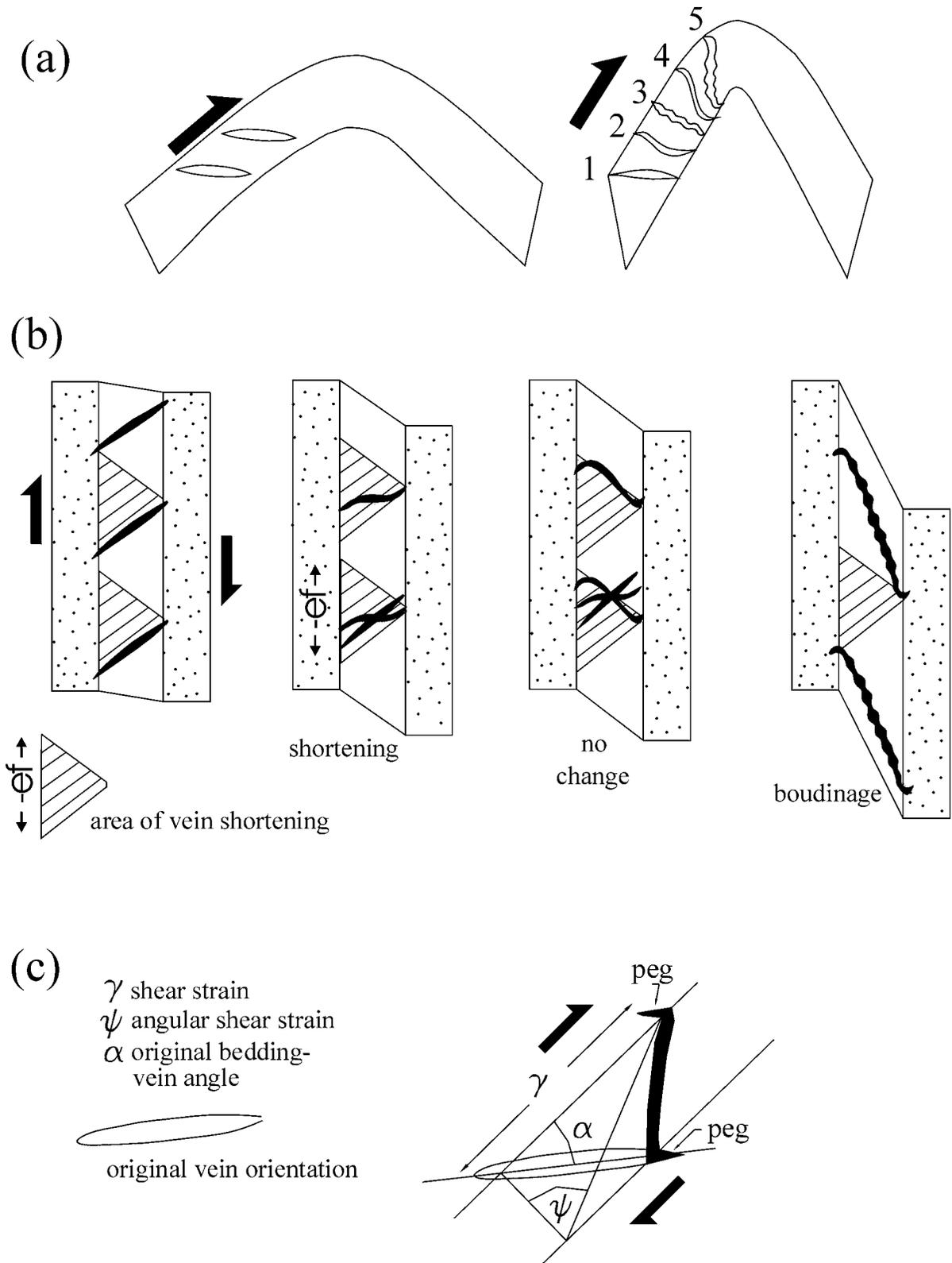


Figure 7. Diagrams showing the formation and progressive deformation of en echelon veins on a fold limb (a) (after Ramsay and Huber, 1987) and in a general shear zone (b) (after Ramsay and Huber, 1983). (c) Sketch showing the shear strain recorded by deformed en echelon veins. Note that the original orientation of the vein to bedding (α) is determined from the pegs within metasandstone.

the structurally highest, as saddle-reef 1a, 1b and 1c (Figs. 2b, 5a). Due to the closeness of the saddle-reef veins, only saddle-reef 1a was mined, although development work has locally exposed all three saddle-reefs. Saddle-reef 1a is asymmetric with respect to the fold, defining a crescent-shaped vein extending from the fold hinge down the north limb (Fig. 5c). The maximum thickness is 1.3 m. The saddle-reef vein is composite, consisting of mainly massive (locally vuggy), quartz with laminated quartz occurring at the margins (Fig. 5e). The saddle-reef progressively tapers down the north limb and, within approximately 10 m, is represented by a thin (~6 cm) laminated bedding-parallel vein and minor en echelon veins (Fig. 5d). On the south limb, the saddle-reef is represented by a laminated vein starting at the fold hinge. The massive quartz invariably cross-cuts the laminated vein, suggesting a history of laminated vein formation followed by emplacement of massive quartz. Movement horizons occur at the hanging wall contact of the vein and a significant shear zone, including en echelon veins and movement horizons, is locally developed in the hanging wall of the south limb. Some movement horizons on the south limb are defined by 1-2 cm thick zones of fault gouge (clay) with angular quartz clasts. This shear zone and related en echelon veins may be analogous to the “leather jacket” structures defined in the Victoria deposits of Australia (Baragwanath, 1953; Hodgson, 1989). Significant arsenopyrite (a few percent) occurs as coarse crystals and clots within the vein and is disseminated throughout the adjacent wall rock.

Saddle-reef 1b is locally exposed and is relatively thin (max. 20 cm). The leg-reef on the south limb consists of en echelon shear veins right up to the hinge zone. Saddle-reef 1c is locally exposed in a crosscut. This saddle-reef is similar to saddle-reef 1a in size and geometry: it has a maximum thickness of approximately 1 m and is asymmetric, defining a crescent-shaped structure which extends from the hinge down the north limb. Laminated veins occur at the margins of the predominantly massive quartz saddle-reef vein. On the north limb, the leg-reef vein is defined by massive bedding-parallel vein and en echelon shear veins.

Saddle-reef veins 1a, 1b and 1c occur within slate intervals and their leg-reefs are interpreted to represent flexural shear structures. Abundant evidence of flexural shear is found in slate horizons adjacent to the leg-reefs of these saddle-reefs (Figs. 5b). The leg-reefs of saddle-reefs 1a and 1c are observed at significant distance down the north limb (exposed at the ~1060 level, Fig. 5a, and the 1020 level, Fig. 6a), represented by laminated bedding-parallel veins and (or) en echelon shear veins.

Saddle-reef 2

Saddle-reef 2 includes two saddle-reef veins, referred to as 2a and 2b (Fig. 6a). Saddle-reef 2a is larger and was mined for approximately 500 m along strike (Fig. 2c). Exposures of saddle-reef 2b are restricted to the leg-reefs.

Saddle-reef 2a Saddle-reef 2a is large, measuring approximately 4+ m in height and 4+ m across the base (e.g. Fig. 6c). The saddle-reef vein consists mainly of massive quartz with variable amounts of slate inclusions. The general shape is triangular, being defined in general by bedding. However, this saddle-reef is also strongly asymmetric, with a thick leg-reef extending down the north limb, whereas only a minor leg-reef extends down the south limb. The saddle-reef occurs within a slate-metasiltstone interval, commonly with black slate in the hanging wall of the vein and a distinct laminated metasiltstone in the foot wall. En echelon shear veins invariably occur in the hanging wall slate on the north limb (e.g. Figs. 6 d, e) and locally define the south limb of the saddle-reef.

The saddle-reef is variable in character and geometry along strike (Figs. 6c, e, f), most notably in the amount of slate wall rock. In general, the amount of quartz progressively decreases to the east. Figure 8e, from just east of fault 1 (line 2400 E), shows the saddle-reef to consist of a series of closely spaced, amalgamated, strongly sheared en echelon veins. The geometry of the individual en echelon veins is evident, defined by horizontal pegs and vertical (sheared) segments separated by septa of slate wall rock. A series of smaller scale en

echelon veins occurs in the hanging wall of the north limb, consistent with this saddle-reef elsewhere. Figure 6f shows saddle-reef 2a at approximately section line 2600 E. The “saddle-reef” at this location is complex, but includes large en echelon veins. Note a zone of vertical, boudinaged (en echelon?) veins in the top centre of the saddle-reef zone.

Leg-reef 2a Mining of the north limb of saddle-reef 2a has provided good exposure of the north leg-reef of this saddle-reef. The leg-reef tapers from about 2 m thickness at the base of the saddle-reef to 10-20 cm at a distance of approximately 7 m down the limb. The leg-reef consists of a massive, coarsely laminated (widely spaced slate? bands parallel the vein margin), bedding-parallel quartz vein with a zone of en echelon shear veins in the hanging wall (Fig. 6d), similar to the main saddle-reef vein. The en echelon veins are strongly boudinaged, reflecting high shear strain. Discordant veins are abundant in the foot wall of the saddle- and leg-reef; however, they do not cross-cut the latter or occur in the hanging wall. Arsenopyrite is common (few percent) within the vein and wall rock. Coarse gold is common and is generally associated with galena in the leg-reef.

Leg-reef 2b Saddle-reef 2b is not exposed, although both the north and south leg-reefs of this saddle-reef are exposed in the ramp at an elevation of 1016 m (Fig. 6a). These leg-reefs are variable in character, and include laminated bedding-parallel veins (cf. Fig. 5d), massive bedding-parallel quartz veins, and en echelon shear veins. Exposure of the south leg-reef on the east wall of the ramp is particularly notable, consisting of a wide zone (approximately 1 m) of closely spaced (amalgamated) and boudinaged en echelon shear veins (Fig. 6g).

Saddle-reef 3

Exposure of the third saddle-reef structure is limited, with less than 50 m of development on this structure to date. Diamond-drilling suggests there are two saddle-reef veins, 3a and 3b (Fig. 2b); however, only one, presumed to be 3a, is exposed and described here. The hinge zone at saddle-reef 3a defines a broad open arch structure (Fig. 8a, b)

and the saddle-reef vein occurs within a metasiltstone-slate interval, with the vein typically hosted by black slate. Saddle-reef 3a displays asymmetry similar to saddle-reef 1 and 2, with the thickest part of the vein on the north limb (Fig. 8b). The saddle-reef is about 40 cm thick at the hinge, where it locally bifurcates, and thickens slightly on the north limb to approximately 50 cm. Extension down the north limb is not exposed but it is presumed to maintain this thickness for some distance based on comparison with, for example, saddle-reef 1 (Fig. 5c). The saddle-reef thins quickly to the south, where it consists of a laminated vein. The saddle-reef vein includes a laminated vein, which displays some buckling, along the vein margin, with massive quartz forming the bulk of the vein. Arsenopyrite is very abundant, occurring as disseminated crystals and massive clots within the vein and disseminated throughout the wall rock.

Development of Saddle-reef Veins

Formation of saddle-reefs, leg-reefs and related veins in chevron folds is well understood; such veins are associated with structures related to flexural-shear on the limbs and associated hinge zone dilation (e.g. Chace, 1949; Ramsay, 1974; Hodgson, 1989). Saddle-reef veins are often considered in isolation, particularly in discussion of saddle-reef deposits. Additionally, the saddle-reef model is generally presented in the simplest of forms, with development of a triangular void in the hinge of an upright fold, which has experienced a simple history of amplification without hinge migration (Ramsay, 1974). However, fold histories are generally not simple and several structures are known to result from the development of chevron folds simultaneous with classic saddle-reef voids (e.g. Chace, 1949, Ramsay, 1974, Tanner, 1989). Precipitation of quartz in these various structures results in a family of saddle-reef and related veins.

The structure and vein system at the EnvioGold Dufferin gold deposit is readily explained in a flexural-folding, saddle-reef environment. Movement horizons, laminated veins and en echelon veins are pervasive features, occurring within most slate intervals, and display a movement direction and shear sense consistent

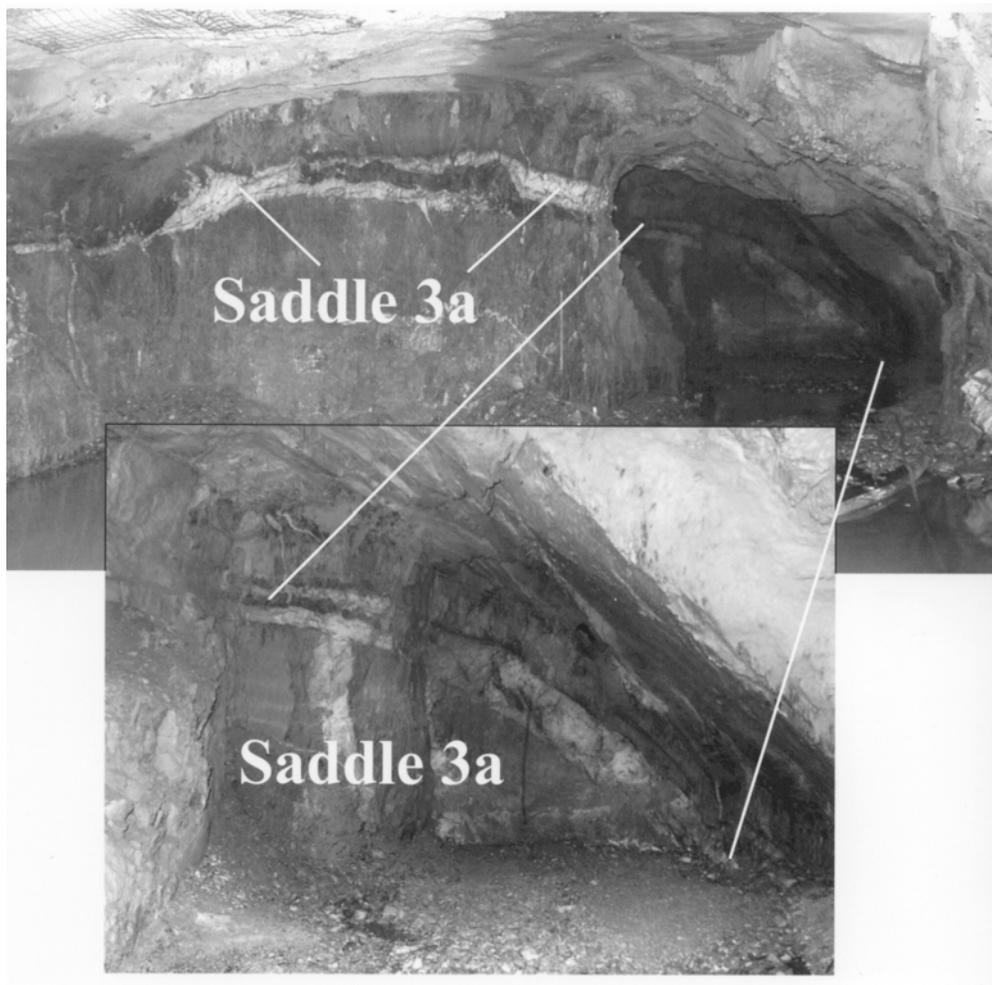
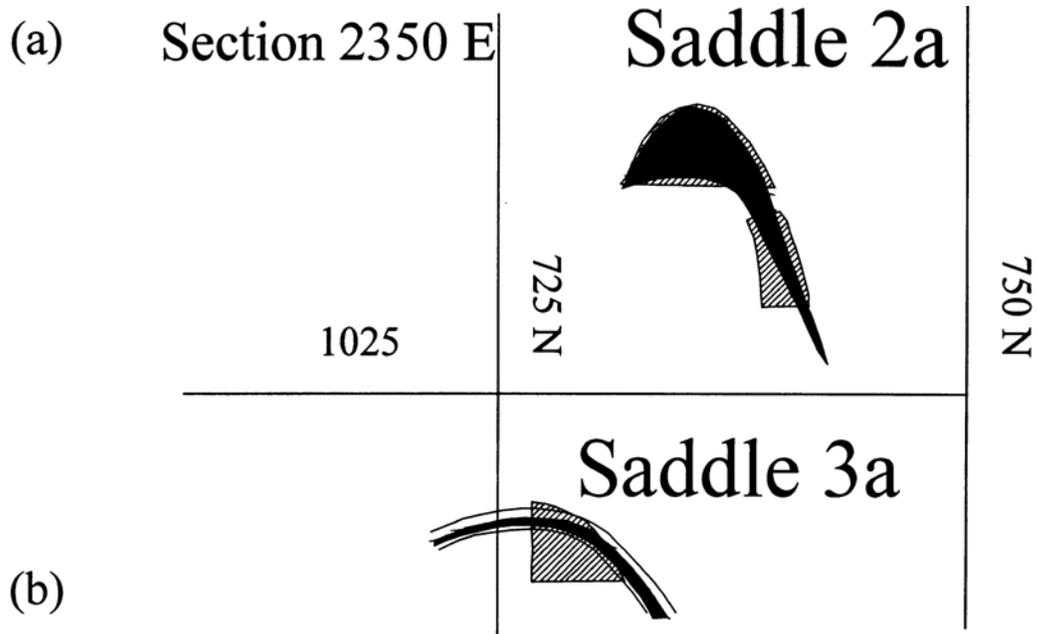


Figure 8. (a) Section at 2350 E showing the geometry of saddle-reef 3a. (b) Photograph of saddle-reef 3a. Inset photograph is a close-up of the north part of the hinge zone and north limb.

with flexural folding. Leg-reef veins in particular are clearly associated with structures resulting from flexural folding and display evidence of syn-folding emplacement (e.g. en echelon shear veins), and a clear connection exists between leg-reefs and saddle-reefs. The various veins occur along common structures and vein relationships suggest synchronous emplacement of all veins. Laminated veins are invariably cut by massive veins, consistent with laminated veins recording the initial shear preceding development of dilational structures filled by massive quartz. The high shear strains recorded by en echelon veins imply that these structures record significant fold amplification. However, shear strain is focused within thin slate layers and large shear strains occur for small changes of limb dip when initial limb dips are high (Ramsay, 1974). Therefore, the shear strain recorded by en echelon veins could reflect a small increment of fold tightening late in the fold history (cf Horne and Culshaw, 2001). Although the saddle-reef veins represent thickened reefs in the hinge zone, they display characteristics which vary from a simplistic saddle-reef model. Two notable differences include (1) the asymmetry of saddle-reef veins and (2) the significant contribution of en echelon veins to saddle-reef veins.

En Echelon Saddle-reef Veins

En echelon veins are common within the deposit and it has been noted that saddle-reef veins are, at least locally, composed largely of en echelon veins. Saddle-reef 2a, in particular, is locally dominated by large en echelon veins which, for the most part, display a sense of shear consistent with flexural-shear on the north limb (e.g. Fig. 6e). The dominance of en echelon veins in the hinge zone indicates that much of the volume recorded by the veins results from shear, in contrast to saddle-reef voids, and that flexural-shear on the limbs extended into the hinge zone. Tanner (1989) and Ramsay (1974) illustrate extension of flexural-slip movement horizons with associated en echelon veins into, and across, the fold hinge along hinge thrusts (Fig. 9a,b) and the spur veins and leather jacket vein arrays in the Australian deposits reflect bedding-parallel faults which extend beyond the

hinge, locally connecting with bedding-parallel movement horizons in adjacent folds (Hodgson, 1989). Development of these structures may reflect “accommodation structures” resulting from variation in thickness of competent layers (Fig. 9b; Ramsay, 1974) or formation of conjugate faults accommodating post-folding shortening.

There is significant variation in bed thickness (note the anomalous thick metasandstone bed above saddle-reef 2a, Fig. 6a) so that “accommodation structures” would be expected. However, the saddle-reef veins within the deposit are generally stratabound and there is no clear evidence of cross-cutting thrusts in the hinge zone. Indeed, the en echelon veins in the hinge do not pass the fold hinge and, furthermore, the en echelon veins in the hinge (saddle-reef) are an extension of those on the limb (leg-reef). The thick zone of en echelon veins in the hinge region may simply reflect thickening of the slate layers in the hinge zone, typical of chevron folds (Ramsay, 1974). Flexural shear strain is restricted to slate horizons. Therefore, as slate layers hosting en echelon veins thicken towards the hinge zone, the size of the en echelon veins increases accordingly (Fig. 9c).

Saddle-reef Asymmetry

As outlined above, the saddle-reef veins have a pronounced asymmetry, with saddle-reef development mainly in the hinge and north limb of the fold. Similar asymmetry was noted in Australian deposits by Chace (1949), although no explanation was provided. For saddle-reef 2a, where en echelon veins are an important component, the asymmetry may simply reflect variance in the shear strain between limbs. This variance in shear could reflect variance in limb length and/or limb dip; the north limb is both shorter and steeper than the south limb. However, this is not apparent for saddle-reefs 1 or 3, where the proportion of en echelon veins is less apparent. The massive and vuggy quartz that constitutes the saddle-reef is interpreted to have formed within structurally developed dilation zones and, therefore, saddle-reef asymmetry is a question of asymmetric dilation.

Asymmetry of the saddle-reefs may also reflect profile shape changes of the fold during fold development. Fowler and Winsor (1996) present several potential shape changes based on experimental modelling of chevron fold development and evaluation of profiles of several chevron folds hosting saddle-reef vein systems (Fig. 9d). They have shown that vertical dilation in the flat segment of a box fold results from limb steepening (Fig. 9e). Saddle-reefs formed in this environment could be transformed onto a limb by fusion of the median segment of the box fold with a limb (Fig. 9e). This explanation is not supported by the en echelon veins in the hanging wall of the saddle-reef, which show opposite sense of shear on either side of the existing fold hinge. However, these veins may record the late shear associated with box fold to chevron transition. The contribution of profile shape change during folding to the asymmetry of the saddle will be better understood with exposure of additional saddle (fold hinges) at depth.

Comparison with Central Victoria

The vein system of the EnviroGold Dufferin deposit is similar to saddle-reef deposits of central Victoria, Australia. Chace (1949) described the Australian vein systems as including saddle-reefs, leg-reefs, neck-reefs and spurs associated with bedding-parallel faults, dilation in the hinge, and dilations associated with faults. The veins are composed of massive and laminated quartz, quartz breccia and brecciated quartz, and the distribution of laminated and massive quartz is similar to the EnviroGold Dufferin deposit: laminated quartz is restricted to leg-reefs and the margins of saddle-reefs. En echelon veins, referred to as “leather jackets” in Australia, are documented along limb thrusts associated with the saddle-reef veins (Baragwanath, 1953).

Age of Veins

$^{40}\text{Ar}/^{39}\text{Ar}$ ages of 388 Ma and 403 Ma, obtained for slate within and adjacent to veins in the portal area of the EnviroGold Dufferin deposit, have been interpreted to reflect metamorphism (Kontak *et al.*, 1998). No isotopic dating of the veins has been attempted. However, $^{40}\text{Ar}/^{39}\text{Ar}$ ages for vein

minerals in other Meguma gold deposits of ca. 370 Ma are consistently younger than $^{40}\text{Ar}/^{39}\text{Ar}$ ages for whole-rock samples from the same deposits, which record metamorphism (Kontak *et al.*, 1998). This has been interpreted to indicate a post-metamorphic age for vein emplacement (Kontak *et al.*, 1998). Horne and Culshaw (2001) also proposed a post-metamorphic age for vein emplacement, which they relate to a late, flexural-slip re-activation of earlier flexural-flow folding.

Several features support a late-folding age for vein emplacement at the EnviroGold Dufferin deposit. Saddle-reefs only develop after significant limb amplification, and formation of flexural shear and saddle-reef structures is accelerated with shortening (Ramsay, 1974). The maturity and pronounced development of the saddles suggest significant fold development at the time of vein emplacement. Flexural shear structures are largely brittle (en echelon gash veins, movement horizons) and clearly deform fold-related cleavage.

Distribution of Gold

Gold was not often noted in the mine and relatively few analytical data are available; thus, the distribution of gold within the deposit is not well understood. However, the following observations can be made. Gold (i.e. visible gold and/or assay results) has been detected within all vein types, including saddle-reef, laminated leg-reef, en echelon and discordant veins. This is consistent with the interpretation of synchronous formation of all veins. The most consistent, and abundant, visible gold was noted in the north leg of saddle-reef 2a, where it commonly occurs near slate septa within the vein. Throughout the deposit there is an apparent positive correlation between visible gold and galena: gold generally occurs within a few centimetres of galena and locally gold decorates galena. Sphalerite is also common near gold in some samples, although less recognizable in the mine. Gold is found decorating arsenopyrite; however, the abundance of arsenopyrite offers no apparent guide to concentrations of gold. Arsenopyrite is common to abundant within all vein types and is disseminated in the adjacent wall rock as a zone of wall rock alteration. Low gold levels occur in wall rock adjacent to veins.

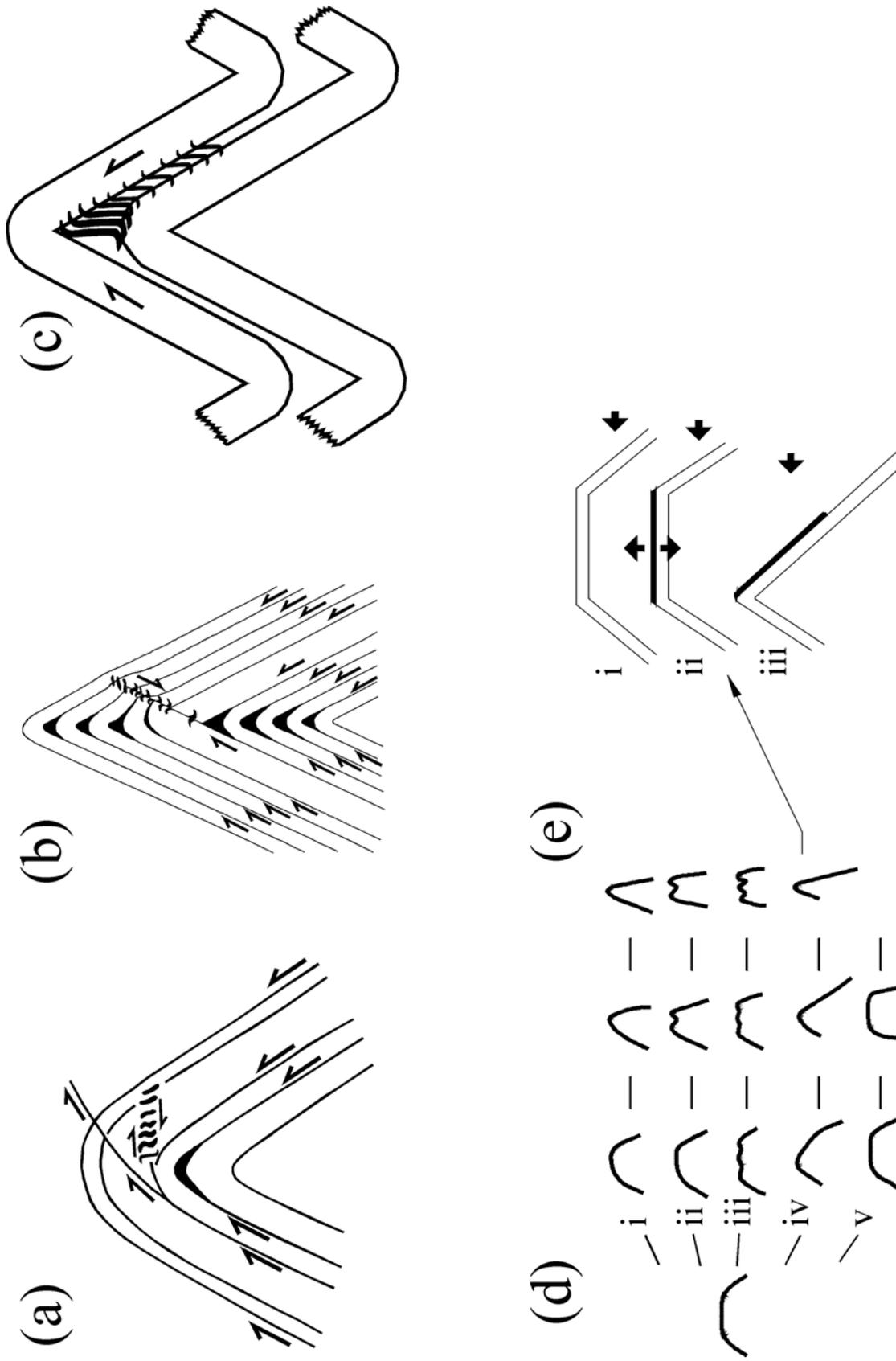


Figure 9. Sketches (a, b) showing the extension of bedding-parallel movement horizons across the fold hinge with associated echelon vein: (a) after Tanner (1989) and (b) after Ramsay (1974). (c) Schematic diagram showing the extension of echelon veins from a limb into the hinge, where they increase in size in response to increasing thickness of the slate interval. (d) Diagram showing possible profile shape change during the transition of box folds to chevrons (after Fowler and Winsor, 1996). (e) Close-up of profile shape change from stage i to ii, and transition of the median segment of the box fold onto a limb during further shortening, resulting in an asymmetric saddle-reef vein.

Much more work is required in order to evaluate the gold distribution and controls on mineralization within the deposit. The association of gold with the vein array supports a genetic relationship; however, secondary features of a chemical or structural nature may well control the distribution and abundance of gold within the vein system.

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