The Kemptville Shear Zone: Regional Shear Related to Granite Emplacement and Mineralization

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Introduction

The Southwest Nova Scotia tin domain (Fig. 1) is a zone of tin and base metal mineralization in southwestern Nova Scotia (Chatterjee, 1983). O'Reilly and Kontak (1992) and O'Reilly *et al.* (1992) recognized that many mineral occurrences in the area along the north edge of the South Mountain Batholith near East Kemptville, and others in the Wedgeport area lie within shear zones, collectively referred to as the East Kemptville Shear Zone (EKSZ; Fig. 1). Evidence supports a syn-tectonic origin for much of this mineralization (Halter *et al.*,1994; Soehl *et al.,* 1989; O'Reilly and Kontak, 1992; O'Reilly *et al.*, 1992) and the EKSZ is considered important to the localization of mineralizing fluids related to late, evolved phases of the South Mountain Batholith (O'Reilly *et al.,* 1992; O'Reilly and Kontak, 1992).

The Kemptville Shear Zone (KSZ) is a distinct zone extending from Carlton east toward East Kemptville (Fig. 2), and marks the northern limit of the EKSZ in that area. In contrast to the tin and base metal mineralization in the EKSZ, the KSZ hosts several gold occurrences. Although there have been preliminary investigations of the KZS (e.g. O'Reilly *et al.*, 1992), a detailed investigation of the structural character and tectonic significance of the shear zone or its relationship to mineralization has not been undertaken. In this paper we present preliminary results of field and petrographic studies that address these questions. In addition, we present geophysical data, including airborne magnetic and radiometric surveys and regional gravity data, which are interpreted in relation to granite emplacement, shearing and mineralization in the area.

Geological Setting

The Meguma Terrane (Fig. 1) records a relatively simple geological history. The oldest units include the Meguma Group and disconformably overlying Silurian to Early Devonian metasedimentary, and associated intrusive, units of the Anappolis Group (Fig. 1). These rocks record Acadian (Middle Devonian) regional folding under greenschist- to lower amphibolite-facies conditions. Widespread intrusion of peraluminous granites occurred in the Late Devonian. These intrusions generally cut the regional fold pattern without disruption (Fig. 1), demonstrating a largely post-tectonic origin. Several features, however, indicate that the region was tectonically active during granite emplacement.

The South Mountain Batholith (SMB; Fig. 1) consists of an early biotite granite to granodiorite stage (Stage 1 plutons) and later lecomonzogranite to lecogranite stage (Stage 2 plutons). The geometry of some Stage 2 plutons suggests emplacement along structures existing within the Stage 1 plutons. For example, the linear trend of the East Dalhousie pluton (EDP; Fig. 1) suggests emplacement along a fault developed in Stage 1 plutons, and northwest-trending dyke-like segments of the New Ross pluton (NRP; Fig. 1) suggest structural influence on emplacement (Horne *et al.*, 1992). Gravity data indicate that the SMB has an elongate northeast-southwest root that extends from the East Kemptville area along the southern margin of the East Dalhousie pluton and north of the New Ross pluton (Fig. 1; Benn *et al.*, 1999). This root has been interpreted as a "feeder zone" of granite intrusion, possibly reflecting a shear zone parallel to the regional structural grain, along which granite intrusion occurred (Benn *et al.*, 1999). Post-granite

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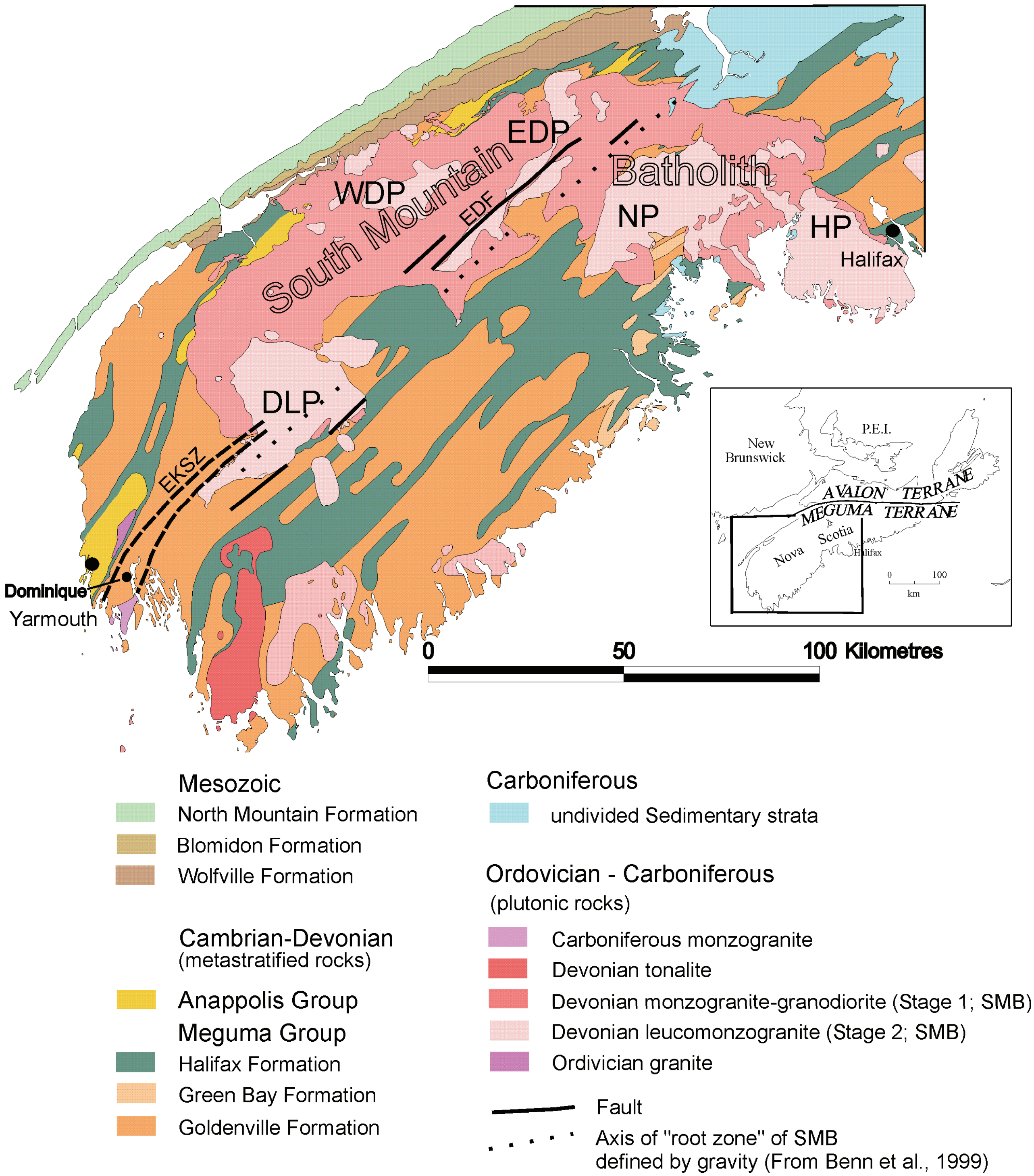


Figure 1. Simplified geology map of western Nova Scotia. EKSZ - East Kemptville shear zone; EDF - East Dalhousie Fault; DLP - Davies Lake pluton; WDP - West Dalhousie pluton; EDP - East Dalhousie pluton; NP - New Ross pluton; SWTD – Southwest Nova Tin Domain. The East Kemptville tin domain corresponds roughly to the boundaries of the East Kemptville shear zone.

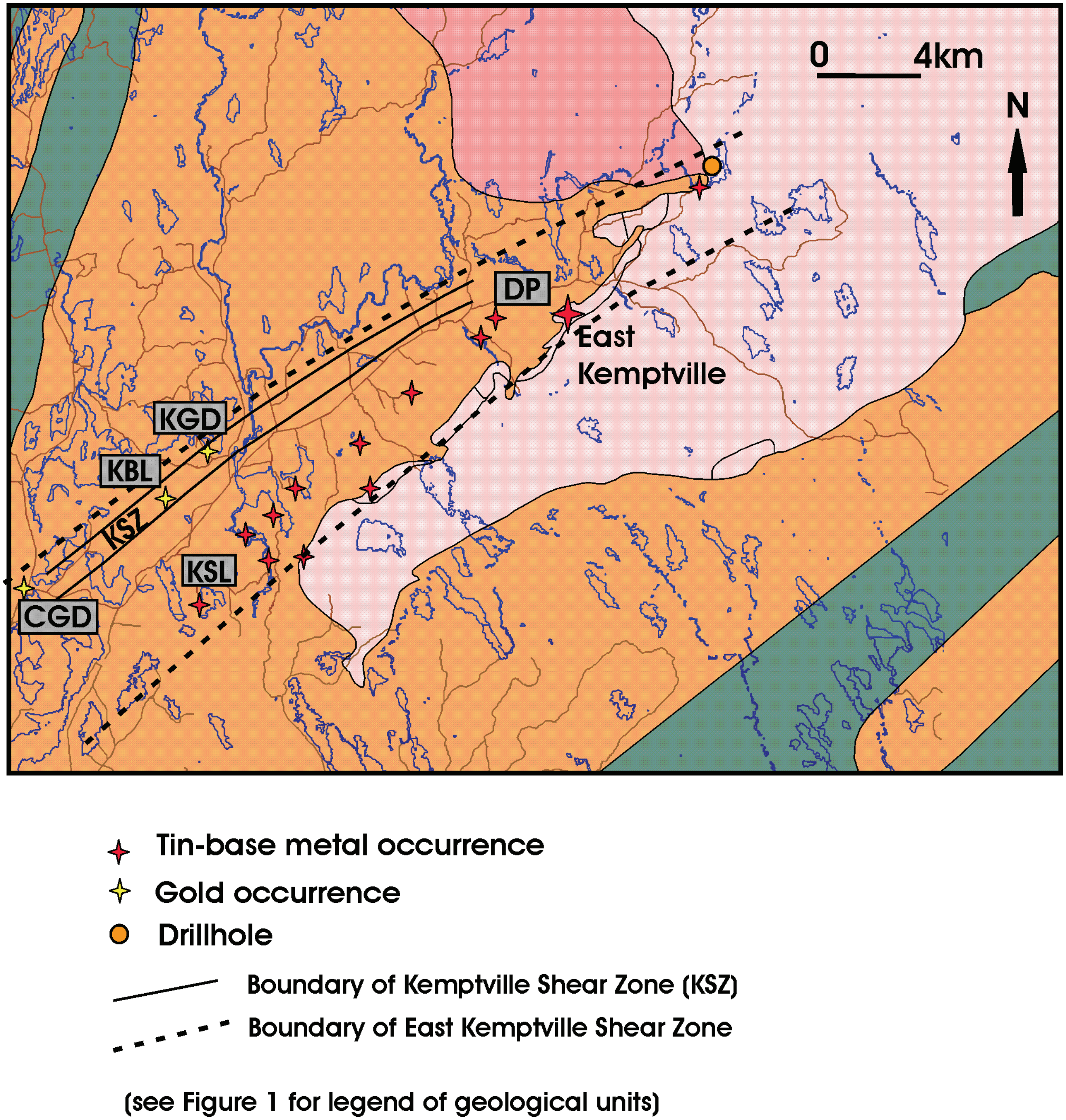


Figure 2. Geological map of the East Kemptville area showing the distribution of the Kemptville and East Kemptville shear zones and mineral occurrences. CGD - Carlton Gold District; DP - Duck Pond tin occurrence; KSL - Kempt Snare Lake occurrence; KSZ - Kemptville shear zone; KGD - Kemptville Gold District; KBL - Kemptback Lake occurrence.

faulting roughly coinciding with this root is documented in the East Dalhousie pluton (East Dalhousie Fault; EDF) and the Davies Lake pluton (EKSZ). These observations suggest active regional-scale faulting that spanned granite emplacement. Vein and fracture patterns (Horne *et al.*, 1992), and planar and linear anisotropy of magnetic susceptibility fabrics (Benn *et al.*, 1997), define regional trends sympathetic to the regional Meguma structural trends, supporting regional deformation during granite emplacement.

Local, narrow, high-strain zones within the contact aureole have been interpreted to reflect either a "lifting of the roof" (Benn *et al.*, 1997) or "floor down" (Culshaw and Bathanagar, 2001) mechanism for granite emplacement (Fig. 3). A floor down model is preferred, based on well-established kinematics within the shear zones (Culshaw and Bathanagar, 2001) and the lack of regional disturbance of country rocks expected if significant lifting of the roof occurred. A floor down model allows for strain to be largely distributed below the top of the intrusion (Fig. 3). The regional shear zones along which intrusion occurred, and the high strain (shear) zones associated with a floor down emplacement mechanism, provide an environment for syn-tectonic mineralization with migration of late-stage granite-related fluids along related structures.

Kemptville Shear Zone

The Kemptville Shear Zone (KSZ) is a regional shear zone extending from Carlton to the area north of East Kemptville (Fig. 2). Faribault (1919) was the first to identify a zone of post-folding deformation in this area, describing "a zone of shearing and fracturing" extending between the Carlton and Kempt Back Lake gold districts. O'Reilly *et al.* (1992) described shallow-dipping "shear fabrics" at the Kemptville gold district and the Kempt Back Lake gold occurrence (Figs. 2, 4) and suggested that this fabric was similar to that noted at the Duck Pond tin prospect (Fig. 2).

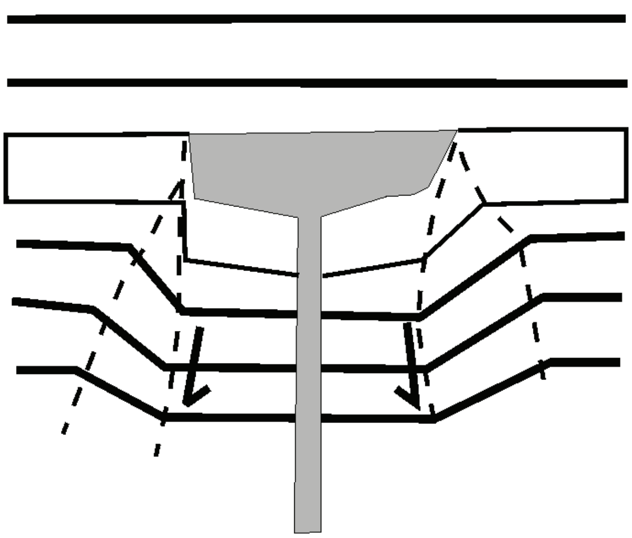


Figure 3. Granite emplacement model of "floor depression mechanism" in the formation of a lopolith (after Cruden, 1998). Note the high strain (shear) zones at the margins of the granite are confined below the top of the granite. The strain adjacent the granite is manifest as a fault on the left and a shear zone on the right.

Recent mapping in the Kemptville area has defined the distribution and character of the KSZ. The shear zone is well exposed in the area around, and west of, the Kemptville Gold District, with local exposures found as far west as Carlton (Fig. 4). Extension of the KSZ east of the Kemptville gold district is based primarily on the occurrence of boulders and till clasts with similar textures, and discontinuity in geophysical data (see below). Diamond-drilling in the South Mountain Batholith where the KZS is projected to intersect (Fig. 2) revealed strongly sheared zones, suggesting the KSZ extends into and deforms the granites. There is no exposure of the KSZ west of Carlton and it is uncertain if it bends to the south, following the general trend of the East Kemptville Shear Zone of O'Reilly (Fig. 1), or intersects the Halifax Formation. We note, however, that float displaying textures characteristic of the KSZ occurs southwest of Carlton and at the Dominique occurrence (Fig. 1).

The known and inferred length of the KSZ is approximately 30 km, and the width, although not exactly defined, is limited to a zone of several hundred metres (Fig. 4). The KSZ defines a distinct, continuous structure and its relationship to other shear zones included in the 'East Kemptville Shear Zone' is unknown. Regional folds are not well defined due to generally poor exposure in the area and, therefore, the relationship of the KSZ to regional fold structures is unknown.

Outcrop in the KSZ

The KSZ is exposed in numerous outcrops in the area between the Kemptville Gold District and Carlton (Fig. 4). Outcrops are characterized by a distinct texture resulting from a well-developed, shallow-dipping fabric (S_2) that crenulates bedding (S_0) and an earlier fabric (S_1) (e.g. Fig. 5). Typical outcrop within the KSZ consists of metasandstone, with or without minor metasiltstone, and bedding

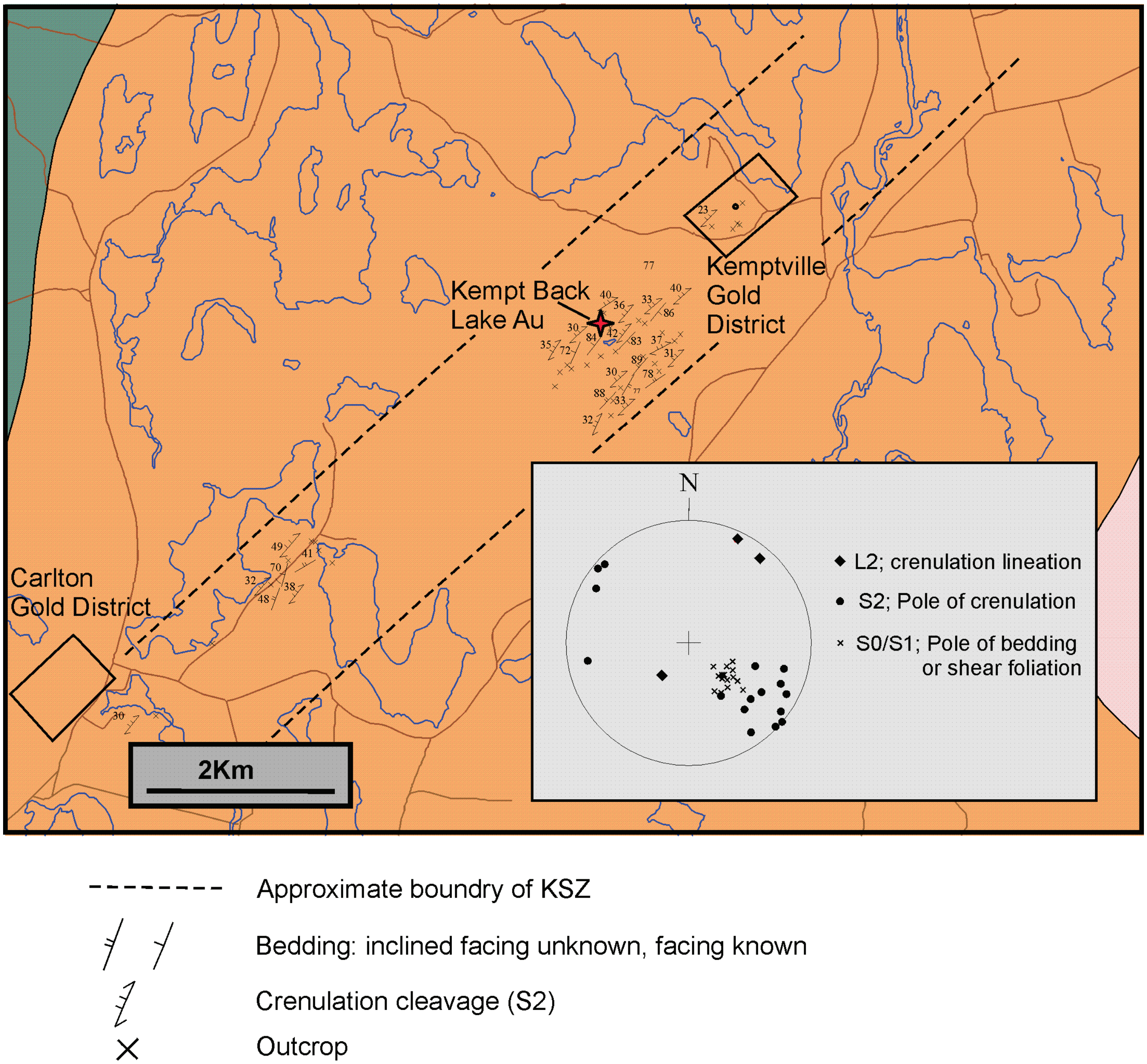


Figure 4. Map of the Kemptville-Carlton area showing exposure of the Kemptville shear zone and steroplots of structural data for the KSZ.

invariably dips steeply, mainly to the north (Fig. 4). There is no evidence of the original fold-related cleavage, inhibiting determination of the structural younging direction. A well-developed bedding-parallel fabric (S_1) occurs, however, defined by a fine continuous cleavage in metasiltstone (Figs. 6a) and variably developed, disjunctive spaced cleavage in metasandstone (Figs. 6b). No lineation is apparent with S_1 and a tectonic origin is not obvious in the field. Evidence of shearing parallel to S_1 is provided by a strong shape fabric in quartz rich layers (Fig. 6a) and locally developed porphroclasts, including mica fish (Fig. 6c), mantled porphroclasts (Fig. 6d), fragmented porphroclasts (Fig. 6e) and opaques with strain fringes (Fig. 6f). Therefore, we interpret this bedding-parallel fabric to represent bedding-parallel shear, which resulted in transposition of earlier fold-related cleavage.

The most obvious feature defining the presence of post-folding shear is a well-developed, shallow-dipping foliation, which locally defines a

(a)

(b)

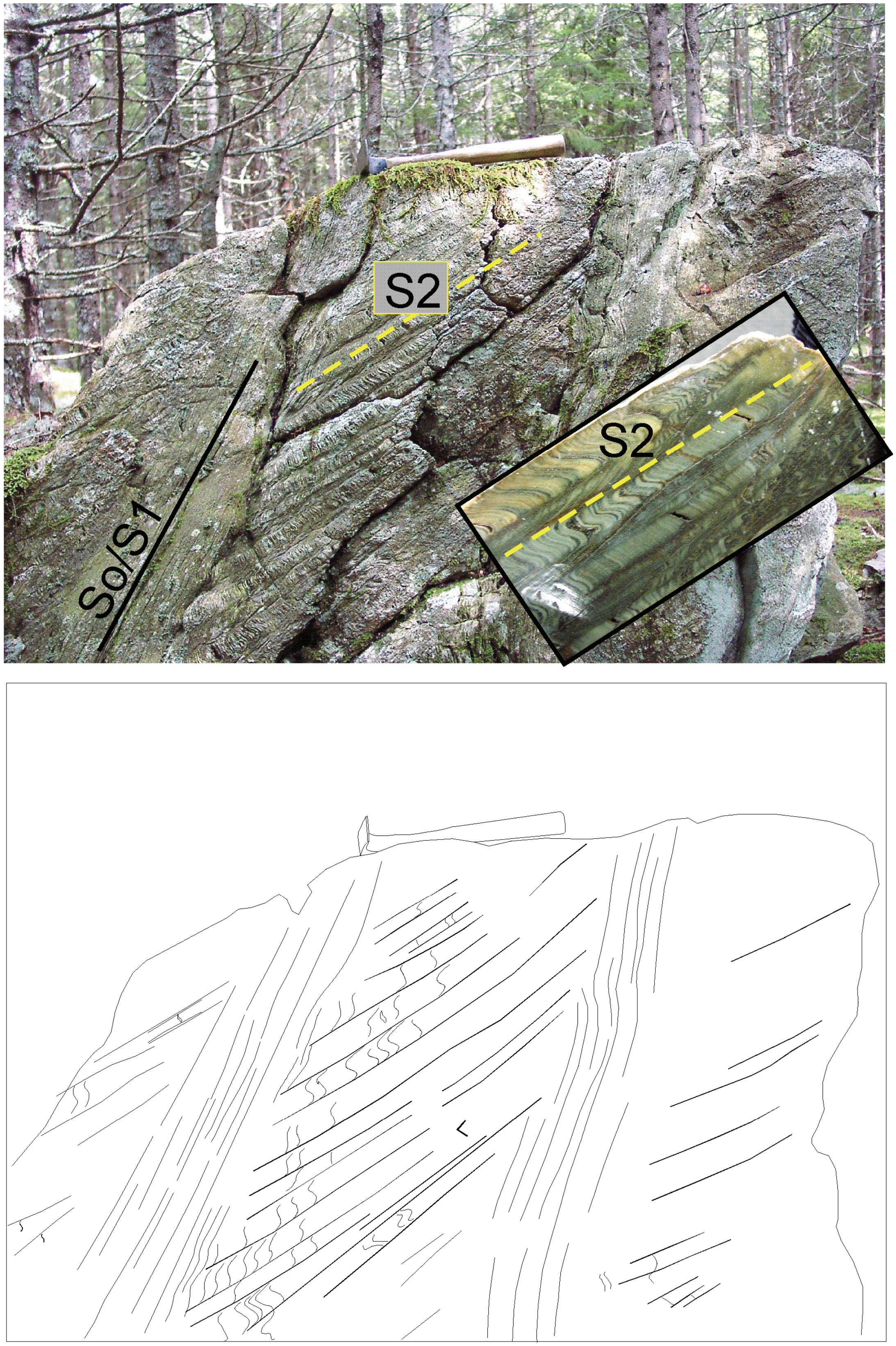
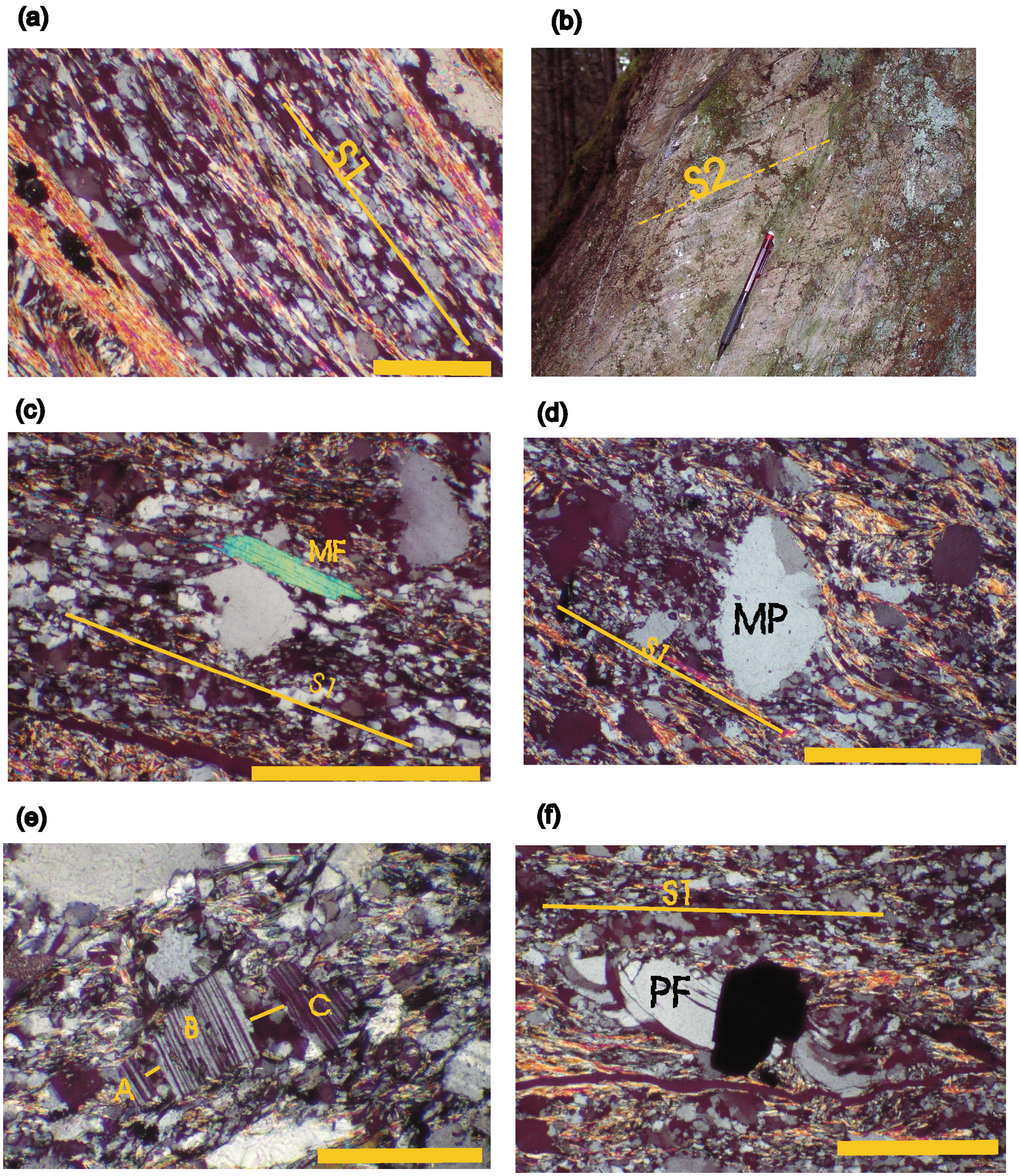


Figure 5. Photograph (a) and corresponding sketch (b) of a typical outcrop of the KSZ. Inset photo in (a) is a cut slab showing close-up detail of structure from of the shear zone. So = bedding, S1 = bedding-parallel shear foliation , S2 = crenulation cleavage.



.**Figure 6.** (a) Photomicrograph of S1 foliation defined by fine continuous cleavage of aligned mica and elongate quartz grains. (b) Photgraph of outcrop showing a tight spaced cleavge (S1) paralle to pencil and a shallow dipping S2 crenulation cleavage. (c) Photomicrograph showing mica fish (MF) porphyroclast in sheared metasandstone.
(d) Photomicrograph showing mantled porphyroclast (MP)in sheared metasandstone (d) Photomicrograph showing mica fragmented porphyroclast, represented by segments of plagioclase labled A-C, in sheared metasandstone.
(e) Photomirograph showing sulfide with quartz pressure fringes (PF) in sheared metasandstone.

penetrative, centimetre-spaced, crenulation cleavage-like fabric (S_2) throughout much of the KSZ (Fig. 5). S_2 development is inhomogeneous at the outcrop scale, being locally well developed in bedding-parallel zones that correspond to metasiltstone intervals and poorly developed or absent in metasandstone (Fig. 5). The S_2 foliation is very uniform in orientation, dipping moderately to the north, and the intersection with bedding and S_1 is shallow (see steroplot, Fig. 4). Folds resulting from 'crenulation' are characterized by strongly thinned limbs and thickened hinge zones (slab inset; Fig. 5). In addition, the folds are highly asymmetric, with a consistent s-fold shape when viewed to the northeast, and hinges are horizontal to shallow-plunging. Hinge zone dilation within crenulation folds is common, resulting in open voids that mimic the asymmetric shape of the folds (Fig. 5). The crenulated bedding and S_1 fabric are locally traceable across several crenulation folds but more commonly are not, and thus the crenulation cleavage is both zonal (Fig. 7a) and discrete (Fig. 7b). Where zonal the enveloping surface of the crenulated S_0/S_1 is counter-clockwise to S_2, consistent with the orientation of bedding determined in outcrop.

Diamond-drill Core from the KSZ

Diamond-drill core from the Kemptville gold district (Fig. 4) intersects wide intervals of the KSZ. Drillholes were oriented perpendicular to the trend of the KSZ and, therefore, provide a cross section of the shear zone. The drill core was oriented using the S_2 fabric as a reference, with the assumption that it has a constant orientation, dipping shallowly to the northwest, as noted in surface exposure. The oriented core provides a cross-section through part of the shear zone.

Notably, bedding has a variable orientation with respect to the core axis, defining mesoscale (decimetre) folds (Fig. 8). The lack of stratigraphic markers, the restricted intersection provided by the core, and the uncertainty of fold geometry limits extrapolation of the folds any distance from the core. Nonetheless, the fold geometry of the mesoscale folds appears similar to the centimetre-scale crenulation folds noted in outcrop (i.e. an S-fold when viewed to the northeast (Fig. 8) and horizontal hinges). The S_2 fabric is well-developed

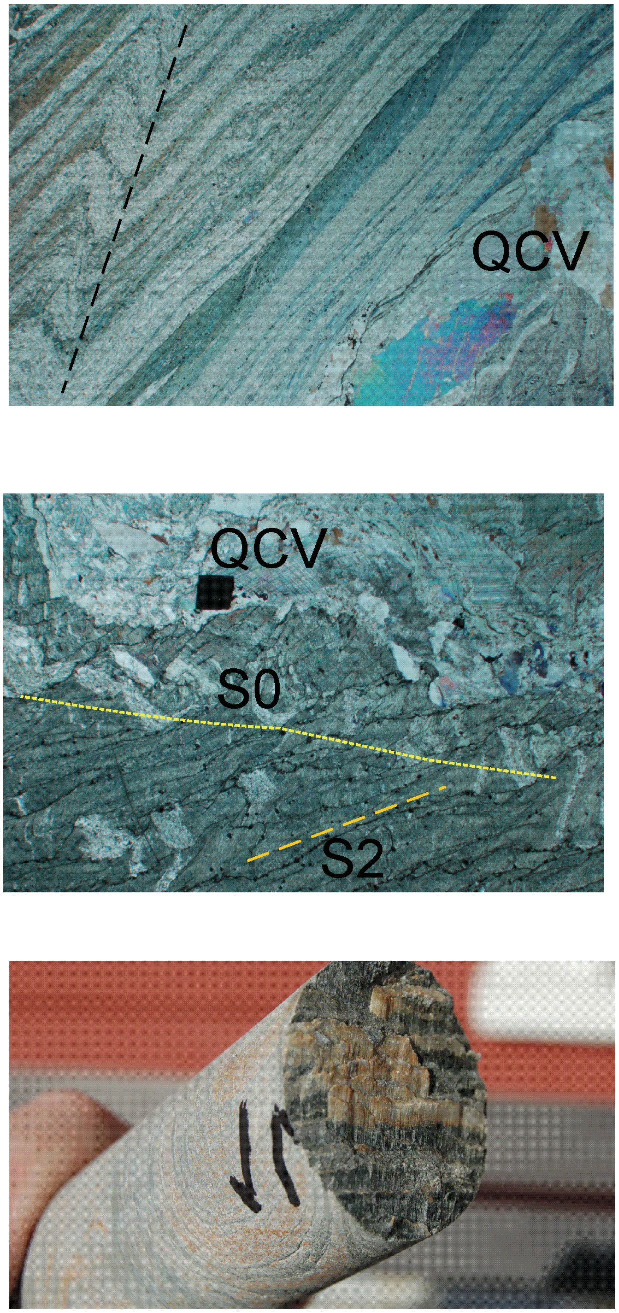
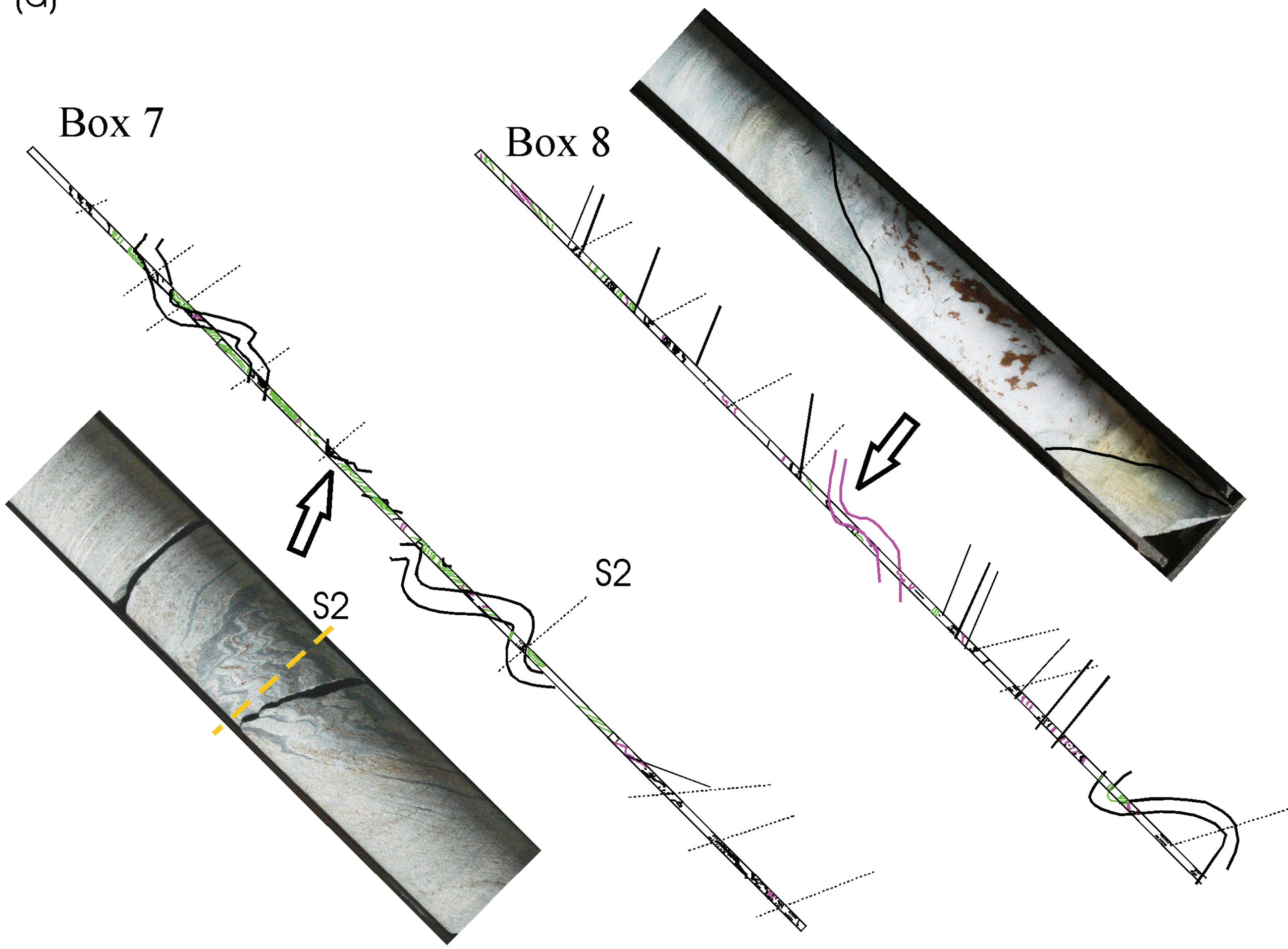


Figure 7. (a) Photomicrograph of zonal crenulation cleavage. (b) Photomicrograph showing well-developed discrete crenulation cleavage (S2) Bedding (S0) is defined by the enveloping surface of thin siltstone layers. Quartz-carbonate vein (QCV) at top is parallel to bedding. (c) Quartz slickenfibres on fracture cutting drill core; shear sense indicated (width of core 3.5 cm).

(a)



(b)

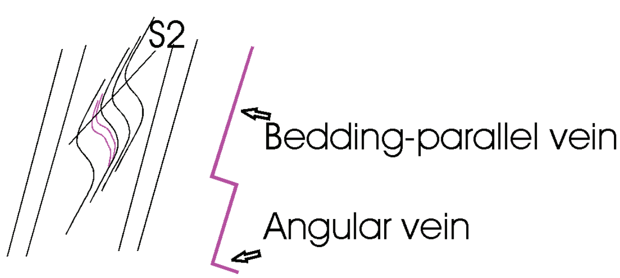


Figure 8. (a) Sketch of gross structure of drill core from the Kemptville gold district. Bedding defined by solid lines, crenulation cleavage by dashed lines and veins by red lines. Photographs of core show folded bedding parallel vein (box 8) and tight fold of bedding with axial planar crenulation cleavage (b) Diagram comparing the relationship of veins within the hinge of mesoscale crenulation folds (left) to the bedding-parallel and angular veins described by Faribault.

and axial planar to the mesoscale folds (Fig. 7c), consistent with these folds being related to the shear zone.

As in surface exposures within the KSZ, no early fold-related axial planar cleavage is apparent in the drill core and the complexity of meso-scale folds makes it difficult to even project the enveloping surface of bedding. Bedding on meso-scale fold limbs typically is clockwise to the core axis (Fig. 8); however, the dip of the enveloping surface of minor folds is uncertain. We note the similarity of meso-scale folds defined in the drill core with the centimetre-scale folds in outcrop, where bedding generally dips steeply to the north. A steep north dip for bedding and/or the enveloping surface of folded bedding and S_1 is consistent with the orientation of "bedded leads" described by Faribault (1919) in the Kemptville gold district (Fig. 8). Uncertainly of facing direction from sedimentary features, and the lack of fold-related cleavage, leaves the structural setting with respect to regional folds completely uncertain.

Slickenfibres are common on fractures cutting the drill core. These fractures are systematic in orientation, approximately parallel to the S_2 fabric (Fig. 8). Although slickenfibres occur on some S_2 surfaces, they also occur on S_1 surfaces oriented parallel to S_2 (fold limbs), or on cross-cutting fractures. The slickenfibres invariably have a down-dip lineation with a top to the south sense of shear (Figs. 7c, 8). Note that the slickenfibres are perpendicular to the intersection of S_2 with S_0/ S_1,and fold hinges, consistent with being kinematically related.

Gold Mineralization in the KSZ

Gold was mined at the Kempt Back Lake Gold District (2,487 oz., Bates 1987) and Carlton Gold District (190 oz., Bates 1987), and other gold occurrences have been documented in the area (Figs. 2, 4). The nature of gold mineralization has always been in question, in particular at the Kemptville gold district, which shows significant variance from other "Meguma gold districts". Faribault (1919) noted that the veins did not occur in the regional fold hinge, as they do at other districts, and suggested veins were "developed along a zone of shearing and fracturing" extending fron the Kemptville to Carlton gold districts. Prest (1894) noted that veins at the Kemptville mine were "a wondering maze of angulars and cross leads." Faribault (1919) described veins at the Kemptville deposit as consisting of generally north-dipping "bedded leads" and intersecting "angular veins." The angular veins had a strike similar to bedded leads but dipped moderaterly to the south, roughly perpendicular to the bedded leads, and the intersection or overlapping segments of bedded and angular veins represented zones of gold enrichment (Faribault, 1919).

In the Kemptville Gold District and the Kempt Back Lake prospect, gold clearly occurs within the KSZ (Figs. 4, 8). The KSZ is exposed in the Carlton River at Carlton, but little evidence of the shear zone is found in dump material at the Carlton Gold District, and the shear zone is thought to swing southward at this point. Significant exploration, including the diamond-drilling mentioned, has been recently undertaken in the Kempville Gold District and Kempt Back Lake prospect and local surface exposures, mineralized float and diamond-drill core provide insight into the nature of mineralization. Structures related to the KSZ are well developed at both locations, but the relation of mineralization to the shear zone is unclear as veins were formed both before and during shear.

Many strongly deformed, bedding-parallel veins were observed in the drill core and some veins are folded by mesoscale shear-related folds (Fig. 8) with smaller veins showing similar relationships to centimetre-scale crenulation folds. Intense strain, recorded by boudinage and recrystalization, is noted in thin section. In addition to deformed veins, there are numerous examples of veins that occupy shear zone structures or cross-cut shear zone fabrics. Quartz-sulphide veins and carbonate occupy the hinges of crenulation-related folds (Fig. 9a), clearly indicating vein development during or after shearing. Locally, quartz veins and related alteration cut all tectonic fabrics (Fig. 9b). Strongly altered samples locally consist of massive, unfoliated quartz-sericite-sulphide that overprint shear-related deformation (Fig. 9c).

It is not clear whether gold mineralization was related to the early, deformed veins or to the veins and alteration that developed in shear-related structures. Visible gold has been observed in several locations and in all instances gold occurs

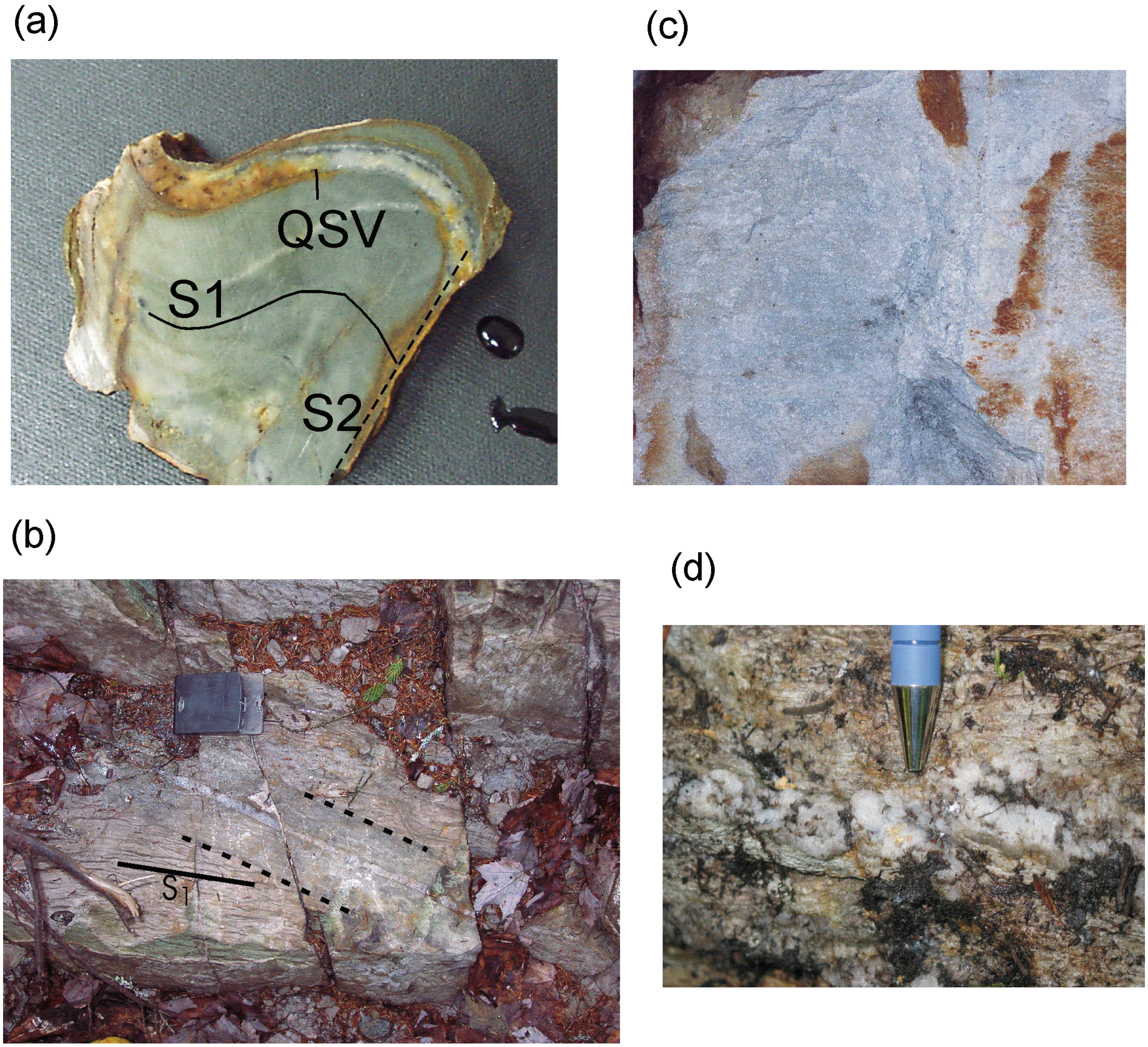


Figure 9. (a) Photgraph of a ct slab showing quartz-sulphide vein in the hinge of a crenulation fold. Wall rock is strongly altered. (b) Photograph of outcrop from the Kemptville gold district showing a late quartz vein with with attending alteration cutting a well developed spaced cleavage (S1). (c) Photograph of massive quartz-sericite alteration which overprints shear zone fabrics. (d) Photograph of gold bearing quartz vein from the Kemptville gold district.

within quartz veins. Many quartz veins intersected by drilling are bedding-parallel, and clearly were deformed by the shear zone. It is possible that these veins represent fold-related veins similar to those of other Meguma gold districts. Quartz veins, alteration and sulphide mineralization, however, are also clearly related to the development of the KSZ. O'Reilly *et al.* (1992) reported elevated gold levels in drill core and trenches at the Kempt Back Lake occurrence were accompanied by elevated levels of antimony (up to 390 ppm).

The geometry of veins described by Faribault (1919) resembles structures of the KSZ. The steep north-dipping bedded veins are parallel to the general orientation of S_0 and S_1, whereas the shallow, south-dipping angular veins generally correspond to the orientation of fold hinges of crenulation and meso-scale folds related to shear

(Fig. 8). Although the veins described by Faribault were unavailable during this study, the similarity of their orientations to shear-related structures and their confinement within the shear zone provide a compelling argument that the gold-bearing veins exploited by previous mining at the Kemptville Gold District are related to shear zone development.

Geophysical Data

A high-resolution airborne geophysical survey was conducted in the East Kemptville area by the Geological Survey of Canada in 1987. These data were acquired and processed for this study by Steve King.

Areomagnetic Data

First and second derivative areomagnetic maps of the Kemptville survey are shown in Figure 10. These maps distinguish between granites, which have low magnetic response, and Meguma Group units, where variable magnetic response reflects magnetic variation between stratigraphic layers. Magnetic patterns characteristic of Meguma Group rocks locally occur within the mapped extent of the SMB (locations A, B, C, Fig. 10a, b). At locations A and B it would appear that the granite contact needs to be adjusted, with continuity of the Meguma Group into areas of granite on the current map. At location C, roof pendants or areas of abundant large inclusions of Meguma are suggested.

Magnetic response within the Meguma Group is less systematic here than in many areas of the Meguma Terrane, and does not record simple patterns that lend themselves to explanation based on stratigraphy and fold structures. In the area of Goldenville Formation along the northwest side of the South Mountain Batholith the linear aeromagnetic patterns characteristic of the Meguma Group are attenuated (location D). This attenuation is represented in both the first and second derivative maps, the latter reflecting near-surface effects, suggesting the magnetic character of the Meguma Group has been altered in this area. A possible explanation for this will be discussed below. We also note that a pronounced linear break in the magnetic pattern coincides with the northern boundary of the KSZ. This break has been used to extrapolate the trace of the KSZ east of the Kemptville Gold District.

Radiometric Data

Radiometric data for the Kemptville survey are presented in Figure 11. These data provide a wealth of information, a full discussion of which is beyond the scope of this paper. Radiometric data reflect near-surface material, either bedrock or components of the surficial deposits. Low radiometric response is recorded over areas of water, for example the areas labelled as lakes (Fig. 11a).

Generally a high radiometric response overlies the South Mountain Batholith, whereas low levels occur over the Meguma Group, allowing for definition of a granite-sediment contact. A sharp gradient occurs at the granite-metasediment contact on the north side of the South Mountain Batholith in the East Kempville area, but the southeren contact is diffuse, with high radiometric levels extending south of the indicated contact. This reflects glacial dispersion down ice (to the southeast) of granite material. The sharp northern contact between the South Mountain Batholith and Meguma Group defines an extremely linear trend, strongly suggesting this contact is structural. A fault contact along this margin is consistent with observations of a fault between the granite and metasediment in the East Kemptville deposit (Kontak, 1987; Halter *et al.*, 1994). We note that the local elevated response in potassium and uranium (labelled SP; Figs. 11b, c, d) represent the stock pile from the East Kemptville mine.

There is an anomalous radiometric response for K and Th over the Meguma Group in the area between the north edge of the South Mountain Batholith and the Kemptville shear zone (Figs. 11a, b) compared to the Meguma Group elsewhere. These data define some linear trends in this area, and may reflect shear zones along which granite-related fluids have migrated.

Gravity Data

Regional gravity data for the area are presented in Figure 12. These data are based on widely spaced data points and only regional-scale trends may be

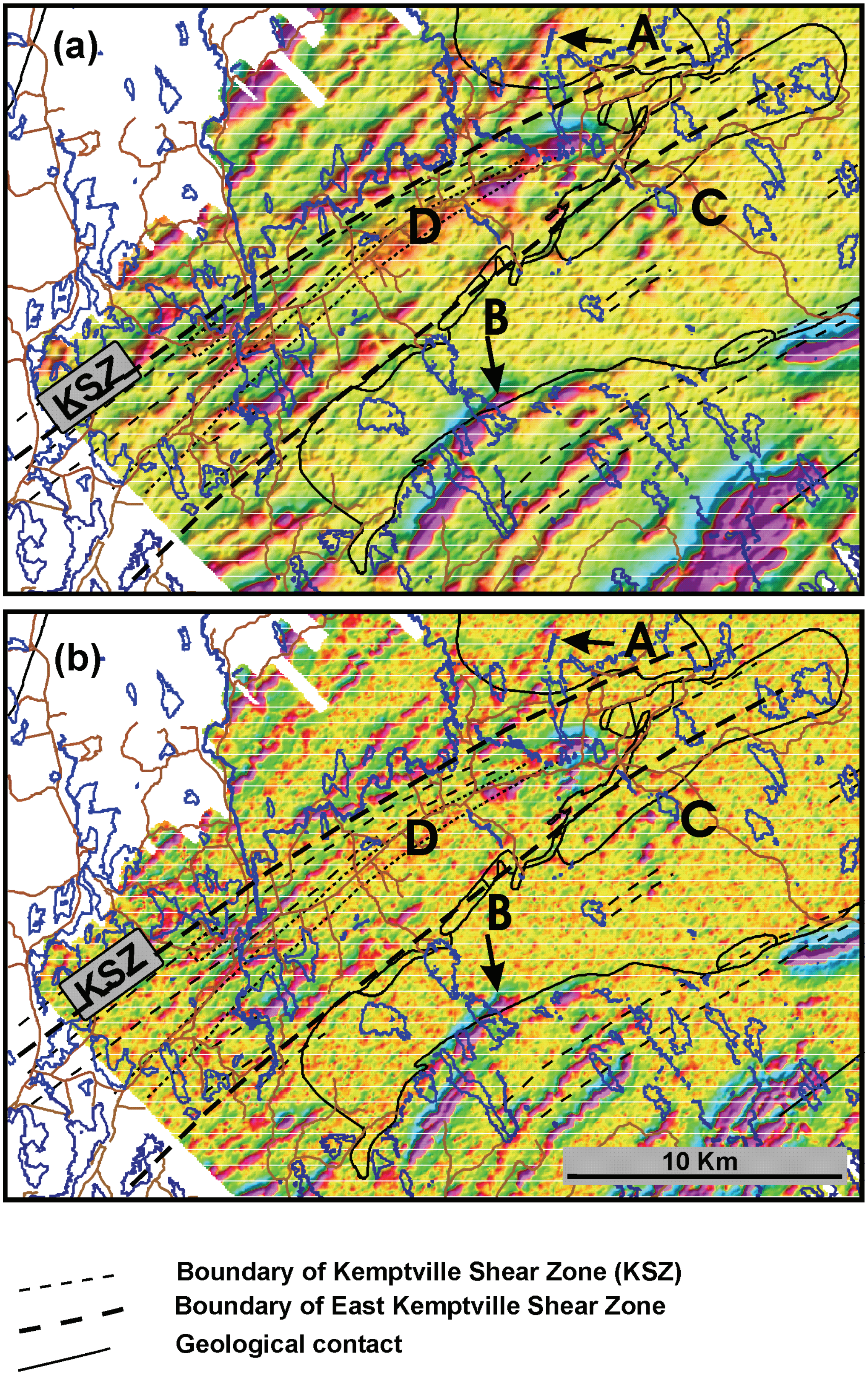


Figure 10. (a) First derivative and (b) second derivative vertical gradient aeromagnetic data for the Kemptville area Geological boundaries as indicated (also compare with Fig. 2). Scale shown on Figure 10b applies to both maps.

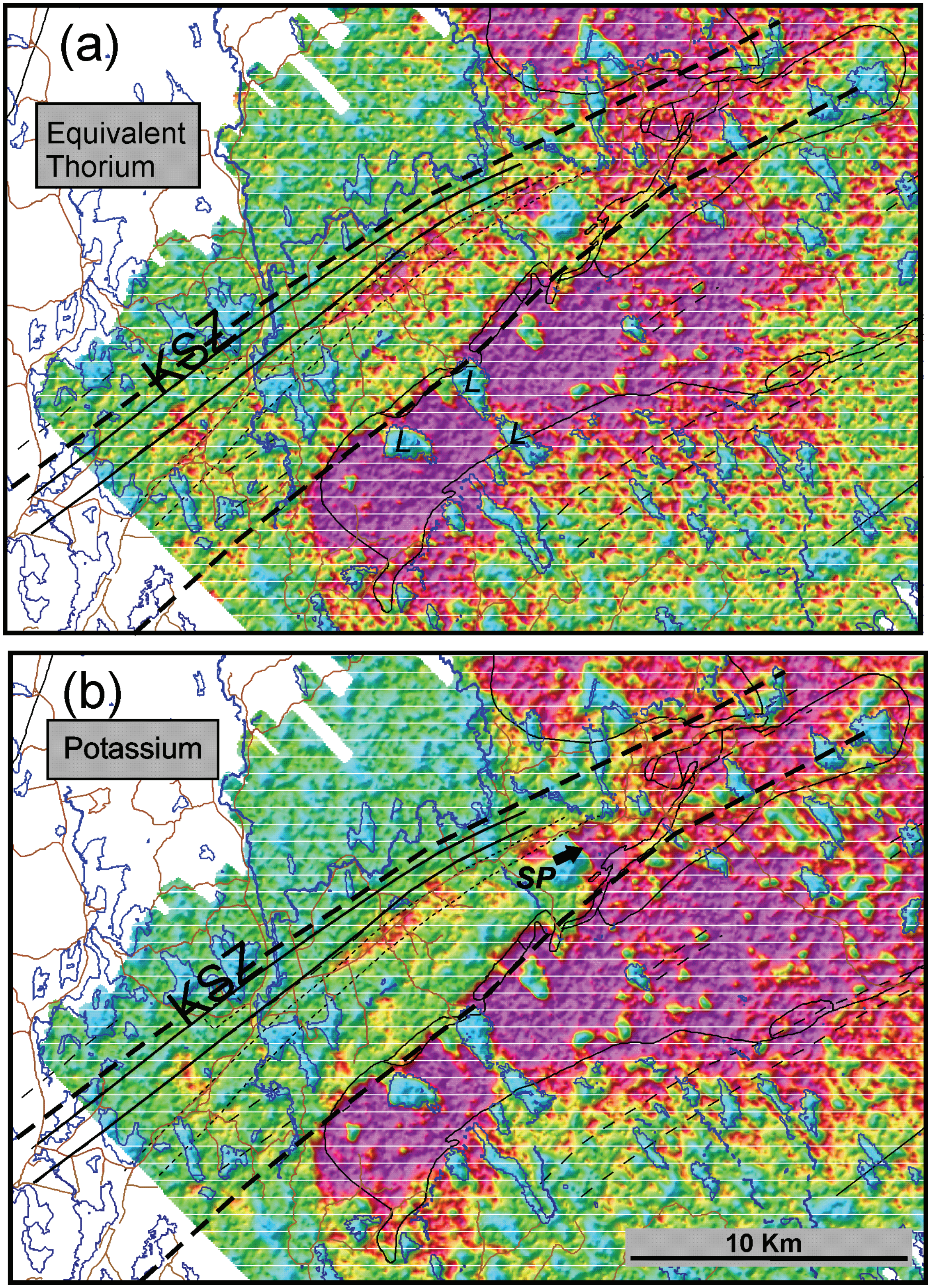
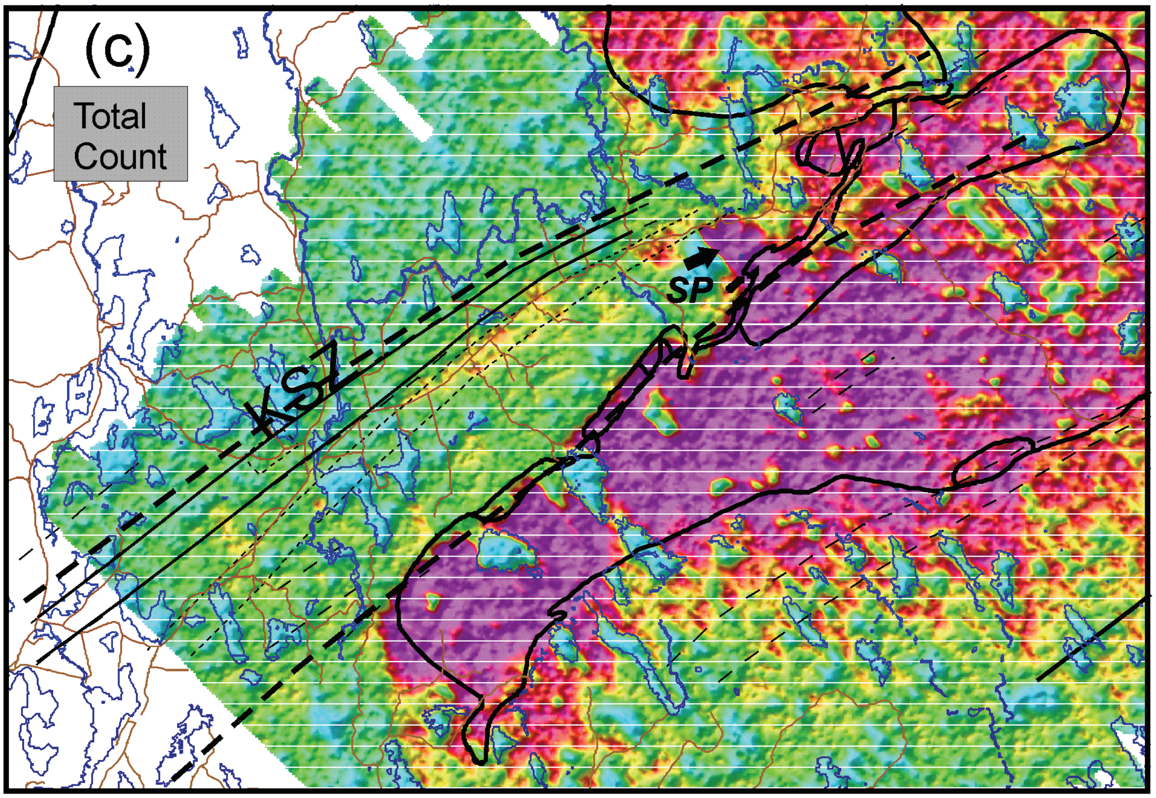
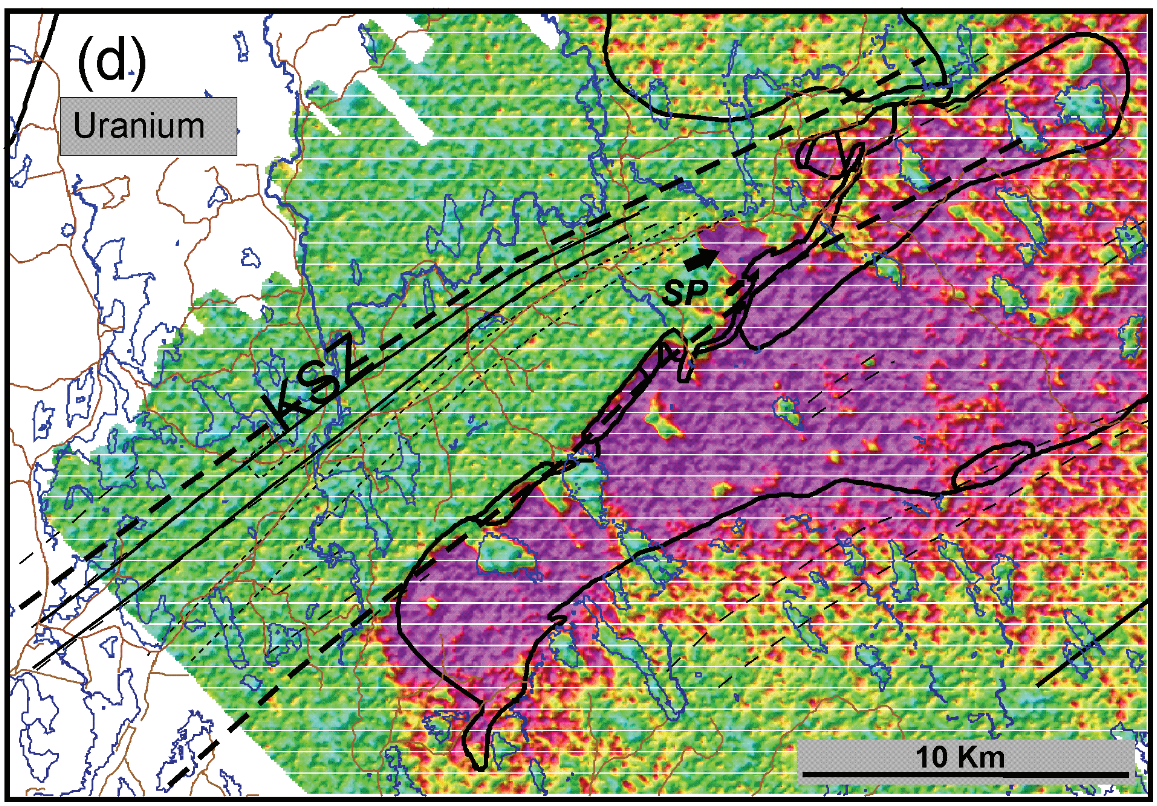


Figure 11. Airborne radiometric data of (a) Equivalent thorium and (b) potassium; **on the facing page** (c) total count and (d) uranium for the Kempville area. Scales shown on the lower figures also apply to the figures above.


(c)
Total Count
KSZ
SP


(d)
Uranium
KSZ
SP
10 Km

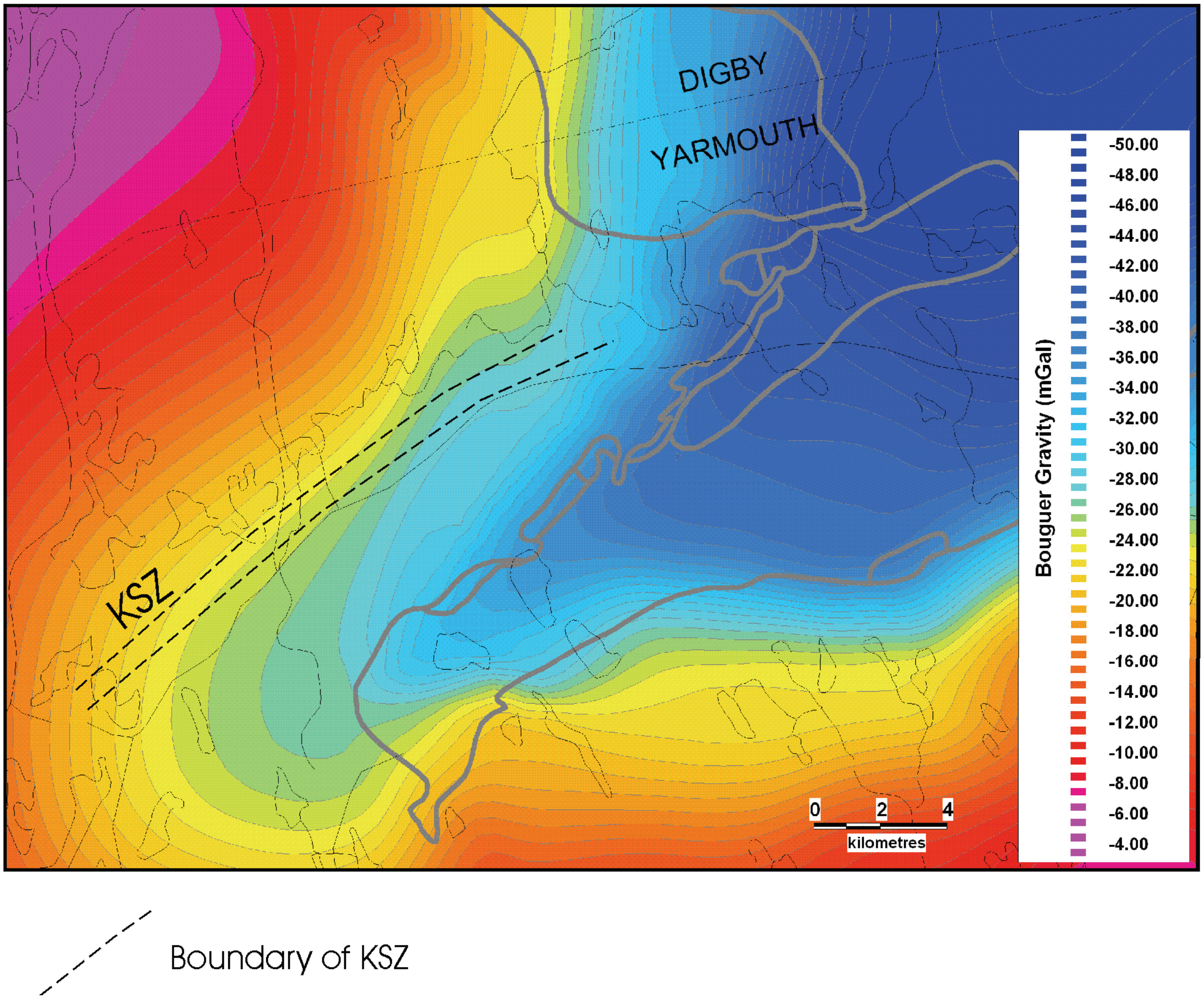


Figure 12. Bouguer gravity data for the Kenmptville area. Geological boundaries for the SMB shown in grey lines (compare with Fig. 2).

resolved. The gravity data generally show a correlation with the South Mountain Batholith in the area, defining a northeast-trending ridge corresponding to the mapped granite distribution. We note, however, that the centre line of this gravity ridge occurs along the northern edge of the mapped granite and that low gravity levels extend well into the area north of the granite contact.

Discussion

The Kemptville Shear Zone

The KSZ defines a significant planar zone of post-Acadian strain, cutting the Goldenville Formation. Classic shear zone fabrics, in particular the lack of a pronounced lineation, inhibit structural and kinematic interpretations, but the restricted planar distribution indicates that this strain defines a shear zone. Crenulation cleavage is the most pronounced post-Acadian fabric, and is critical to understanding the shear zone. Crenulation cleavage can be compressional (compressional crenulation cleavage) or extensional (shear band cleavage) in origin (Passchier and Trouw, 1996). Distinction between compressional crenulation cleavage and extensional shear bands is not always obvious and there has been some confusion in the literature.

Compressional crenulation cleavage reflects folding of an existing fabric, where folds are commonly symmetric, the cleavage is at an angle of >45° to the earlier fabric, and the cleavage zones record pressure solution (Passchier and Trouw, 1996). This definition would seem to fit much of the observed crenulation cleavage in the KSZ, particularily that noted in the drill core (e.g. Fig. 7b). Extensional shear bands are characterized by simple shear, the shear bands generally occur at an angle <45° to the earlier fabric and result in asymmetric folds with back rotation of the earlier fabric. This description would seem to fit a lot of the crenulation cleavage noted in outcrop (e.g. Fig. 5).

Transposition of fold-related cleavage parallel to bedding and various porphyroclasts (Fig. 6) indicate bedding-parallel non-coaxial shear, with dip-slip displacement constained by the shallow intersection of bedding/S_1 with S_2 and crenulation fold hinges. Porphyroclasts do not show pronounced asymmetry and, therefore, do not provide reliable shear sense indicators. Shear sense provided by the crenulation cleavage depends on an extensional (Fig. 13a) or compressional (Fig. 13b) origin. If the slickenfibres on fractures noted in drill core (Fig. 8) are kinematicly related to crenulation development then their shear sense would support a compressional origin for the crenulation cleavage and, therefore, north-side-down displacement on the KSZ (Fig. 13b). The origin of the crenulation cleavage and other structures of the KSZ requires further investigation before the kinematics of the KSZ are confidently understood.

Mineralization, the East Kemptville Shear Zone (Tin Domain) and Granite Emplacement

In addition to the well-known East Kemptville deposit, several tin and base metal occurrences have been documented in the area along the north margin of the South Mountain Batholith and in the Meguma Group in the area between the granite and the KSZ (Fig. 2). Areas of extensive alteration with elevated tin concentrations are also documented throughout this area. Many of these granophile occurrences occur within 'shear zones', which are considered important for migration of granite-related hydrothermal fluids (O'Reilly and Kontak 1992). Evidence for syn-deformational mineralization has been presented for the East Kemptville deposit, where tin-bearing greisens occur along structures parallel to steep, northeast-trending shear zones (Halter *et al.*, 1994) and for mineralization at the Snare Lake occurrence (Fig. 2; Soehl *et al,* 1989). O'Reilly *et al.* (1992) and O'Reilly and Kontak (1991) attributed the numerous tin and base metal occurrences in this area to mineralization within a broad zone of shearing, the East Kemptville Shear Zone, along which deformation spanned granite emplacement. We certainly support this general concept, but emphasise that shearing is inhomogenous and localized along discrete narrow zones. Geophysical data are supportive of a granite-related origin for mineralization in the EKSZ in the Kemptville area. Low gravity data (Fig. 12) are consistent with granite at shallow depths and anomalous radiometric data (eTh, K; Fig. 11) could possibly reflect hydrothermal alteration related to this underlying granite.

As discussed above, active regional-scale shear zones parallel to the axis of the South Mountain Batholith are considered important throughout the history of granite intrusion. In addition, shear zones may develop within the contact zone of intrusions as a result of a 'floor down' emplacement mechanism (Fig. 3). Either deformation mechanism could be responsible for the syn-tectonic granite-related mineralization within the EKSZ. We note, however, that the correspondence of the EKSZ with the 'root zone' of the South Mountain Batholith and the projection of the EKSZ a considerable distance west of the batholith would be consistent with shear related to a regional shear zone along which granite intrusion is interpreted to have occurred (Benn *et al.,* 1999). Indeed, the EKSZ provides the best evidence of the inferred regional shear zone, evidence that has been largely consumed during granite emplacement. Kinematic data are generally lacking for the EKSZ. The KSZ clearly has a dip-slip history, although the sense of shear is not confidently understood. We note that a primarily dip-slip history for the EKSZ would be consistent with its orientation with respect to regional structures recording northwest

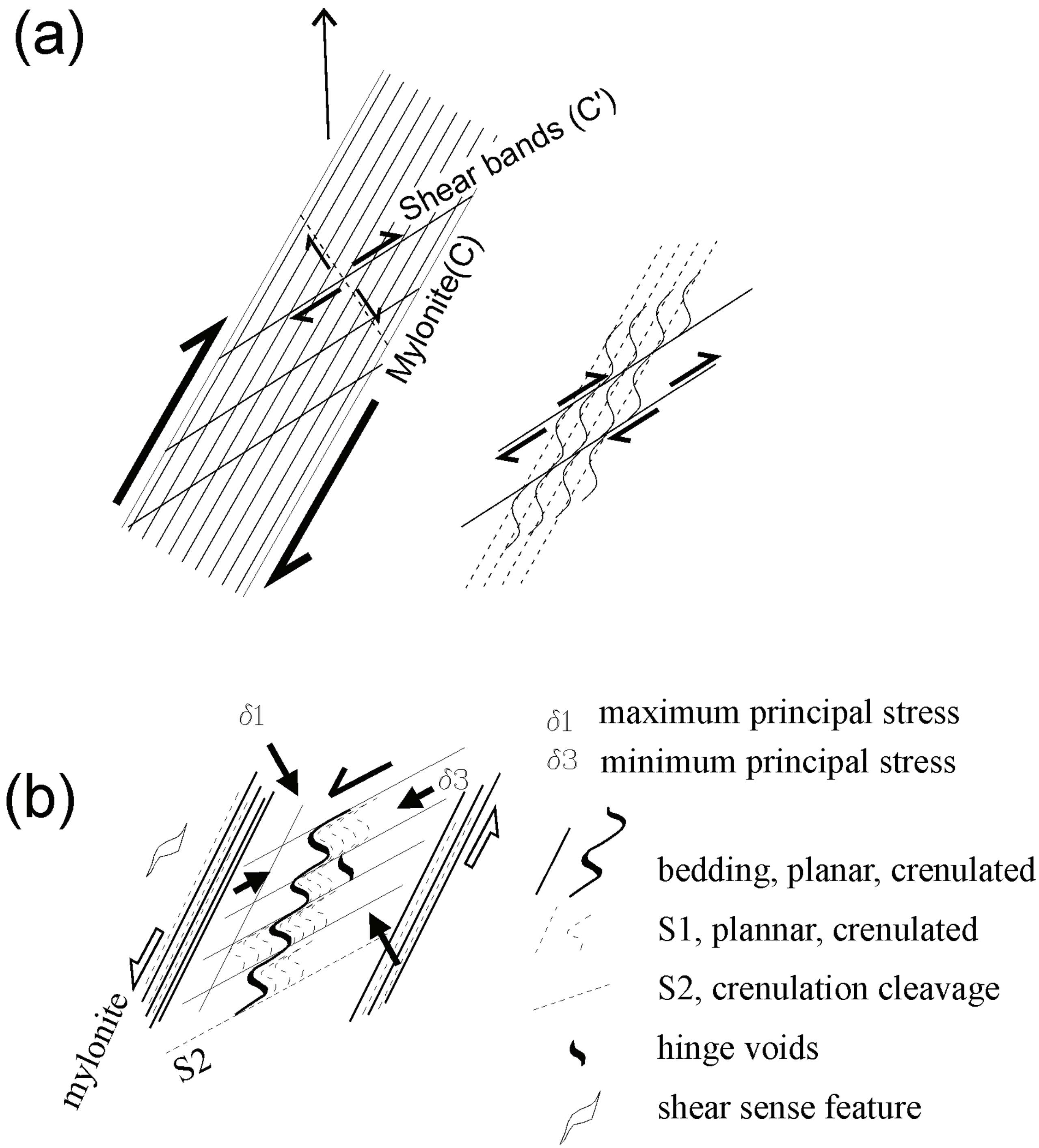


Figure 13. Contrasting models for crenulation cleavage formation in the KSZ. Models oriented with respect to crenulation cleavage, as viewed to the northeast, consistent with earlier figures. (a) Model of extensional shear band development in a mylonite zone, where crenulation cleavage reflect shear bands with back rotation of the mylonitic fabric. (b) Model of compressional crenulation cleavage development resulting from pressure solution cleavage and folding of the brenulated fabric. Note similarity of resulting fabrics.

compression (i.e. Acadian fold hinges (Fig. 1) and planar fabrics within the SMB; Benn *et al.*, 1998; Horne *et al.*, 1992).

Gold mineralization within the KSZ contrasts with the tin and base metal mineralization elsewhere in the EKSZ, and there has been no evidence documented to support a relationship. However, the gold mineralization is associated with a shear zone (KSZ) that is considered part of the EKSZ. We note that gold mineralization in the KSZ is the most distal from the South Mountain Batholith and suggests that this may reflect elemental zonation.

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