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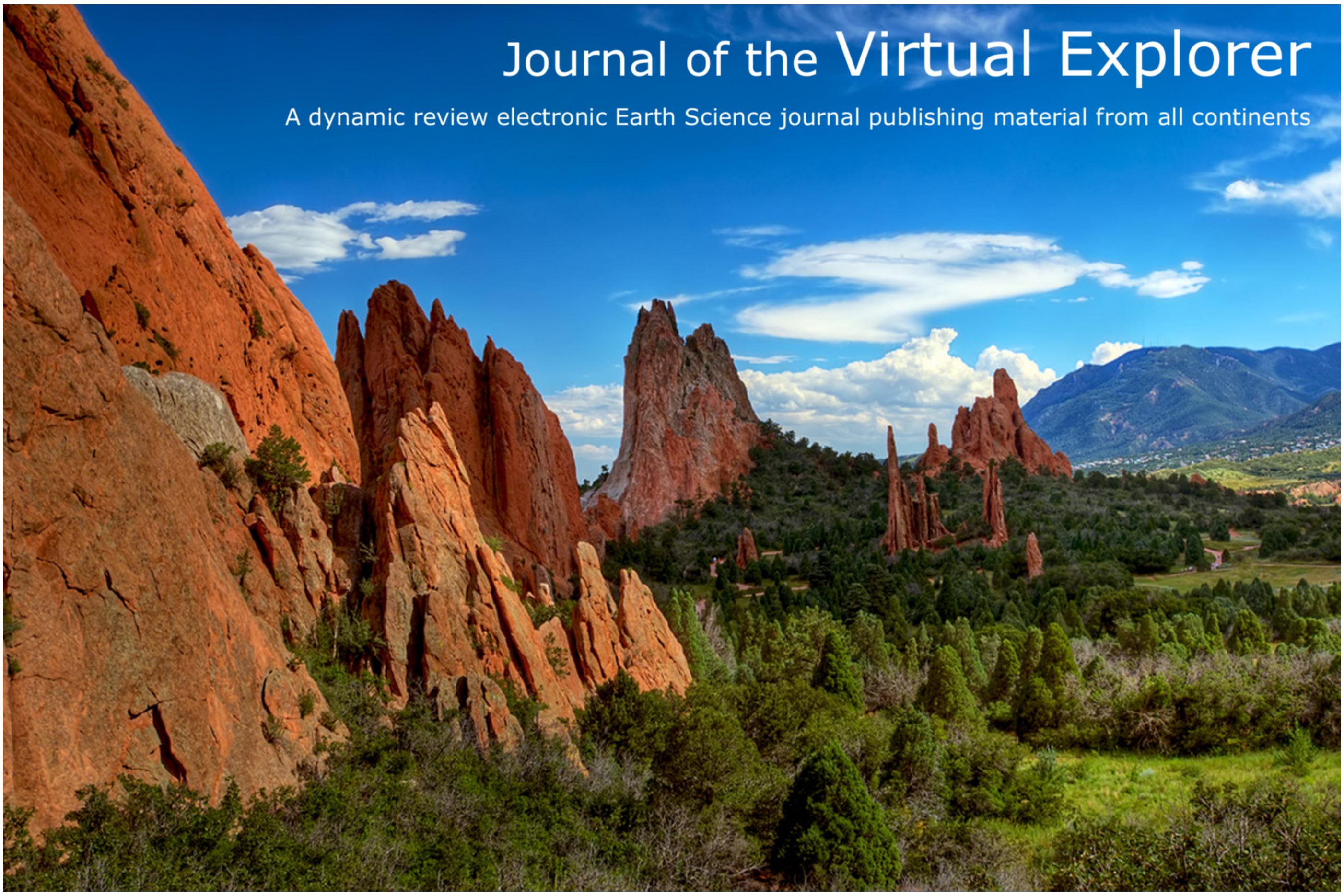

Field Trip to the Base of the Bega Batholith - Day Two

Simon W. Richards, William J. Collins, R.A. Weibe, B. Healy

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Abstract: This is the third in a series of three papers on a "Field Trip to the Base of the Bega Batholith." See http://virtualexplorer.com.au/journal/2007/26/richards/ for the introduction and overview.

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Stop 1 - Wog Wog Mafic Complex

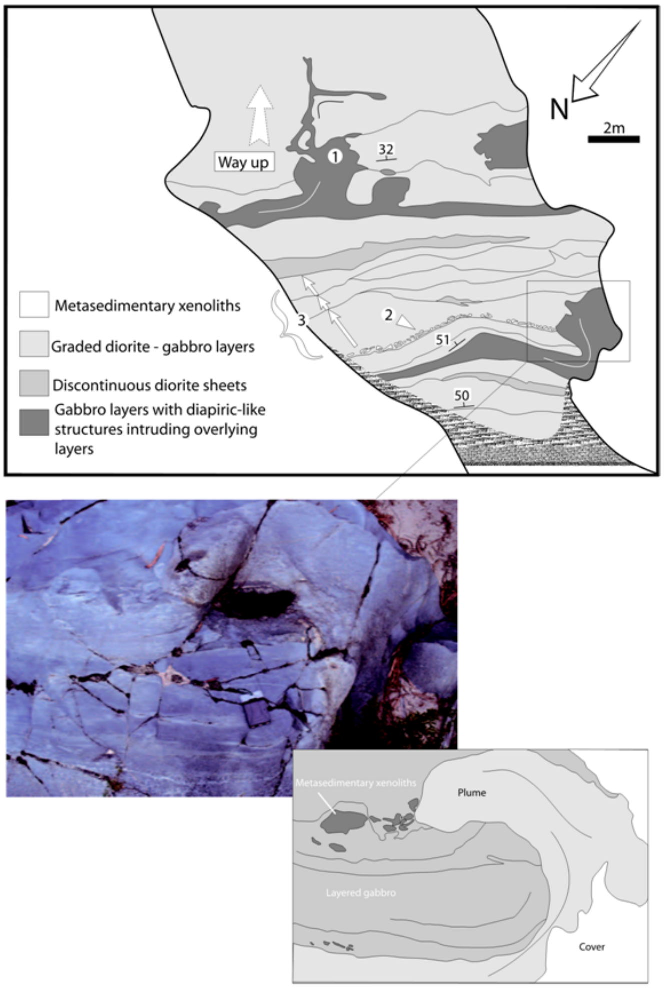
This outcrop lies immediately below the campsite in the Wog Wog River.

The Wog Wog Mafic Complex (WWMC) is a lense shaped, sheeted to strati form body some 2.5 km long and up to 600m wide, striking to the NE and dipping ~50° to the SE. It consists of multiple, metre scale layers of fine to medium hornblende-gabbro layers and coarser grained to oikocrystic, homblende-rich variants. Relict cores of both orthopyroxene and clinopyroxene are locally present in the finer grained phases. Fine grained homblende bearing basaltic dykes cut the complex: some are sub-parallel to the layering and others are oblique at low angles. The latter are easily confused with younger basalts of transitional alkaline character.

A 65m-long representative section of the WWMC exists directly upstream from the Fulligans Track river crossing, immediately below the campsite (Figure 16). Here, the gabbroic layers dip between 30-60° to the SE.

The lower units of the section (to the west) vary up to two metres in thickness and consist of fine to medium basaltic rocks at the base, grading to medium grained, lighter coloured dioritic rocks at the top. Small fragments of very fine grained basalts, representing “rip-up" clasts (Figure 16), are common at this locality. Some of the clasts are also metasedimentary in composition and indicate that some layers, which are now totally enclosed within the mafic complex, must have been in contact with the surrounding metasedimentary countryrock. In other units, more rounded dioritic enclaves appear to have been partially solidified when incorporated.

Figure 16. Map of Rockbar in front of the Campsite



Map of the southwestern end of the rockbar in front of the campsite. This is the type section of the Wog Wog Mafic Complex. It exhibits characteristic layering and stuctures that resemble plumes. The layering is defined by variations in grain size and composition. The base of individual layers is typically fine-grained and basaltic while the tops of the sheets are coarse-grained and doritic to gabbroic.

Farther up the sequence, in the middle section, massive coarse-grained gabbro layers contain large (5 cm diameter) oikocrysts of hornblende set within a matrix dominated by plagioclase. This distinctive unit has a transitional contact with underlying medium grained gabbros, although local intrusive contacts with finer grained units also occur. Much of this layer is obscured by a flat-lying felsic dyke, which links with other smaller felsic dykes and veins throughout the section.

Above the oikocrystic layers, a distinctive gabbro breccia unit forms an irregular body that transgresses the layered complex. Fragments consist of basaltic and dioritic clasts, some of which contain fine laminations that are either planar or convolute. The general angular nature of the clasts, and the discordant contacts of the breccia unit, indicate that it represents a later pulse of gabbroic magma that intruded the more solidified layered sequence, ripping up fragments and transporting them to the site of emplacement. These relations support evidence that the complex was constructed through progressive injection of parallel (sub-horizontal) sheets of mafic material.

The uppermost part of the sequence reflects a return to initial conditions. Metre-scale layered units again show chilled bases and coarsening upward, concomitant with differentiation to more dioritic compositions. Some of the units have a basal section that contains rip-up clasts. Generally, the upper mafic units are coarser grained and more shallowly dipping than their lower equivalents at the bottom of the section. Aplitic and mafic dykes cut the layers.

Way-up indicators

The basal contacts of individual layers tend to be planar and fine grained, suggesting strong under cooling against the underlying unit. Individual units commonly contain "rip-up" clasts of igneous fragments, which suggest derivation from underlying units (Figure 16). The units commonly grade upward into coarser, more felsic (dioritic) variants, illustrating a type of magmatic "graded bedding". This feature and the rip-up clasts indicate that way-up is to the SE, and the whole complex is "right-way-up".

Another major "way-up" indicator are diapir-like structures of medium to coarse-grained dioritic material that have intruded through the layered rocks. In the lowest part of the "type-section" (Figure 16), a discordant intrusive contact between diorite and basaltic layers outlines a 3m-high coliform structure emanating from one of the lowermost coarse-grained dioritic units (Figure 16 and Figure 17). We interpret this structure as a diapir rising from a buoyant differentiated layer in the complex. Another diapiric structure with 2m-high crown is recognised several metres higher in the sequence, and a set of at least three emanate from another felsic layer approximately three quarters of the way up through the section. Elsewhere, narrow layers of coarse-grained gabbro transitional to pegmatite, located directly below basal chilled contacts, reflect accumulation of rising volatiles from the underlying unit trapped against an impermeable upper barrier (Figure 17c). These structures confirm that younging is to the SE.

Figure 17. "Rip-up" clasts of basaltic fragments

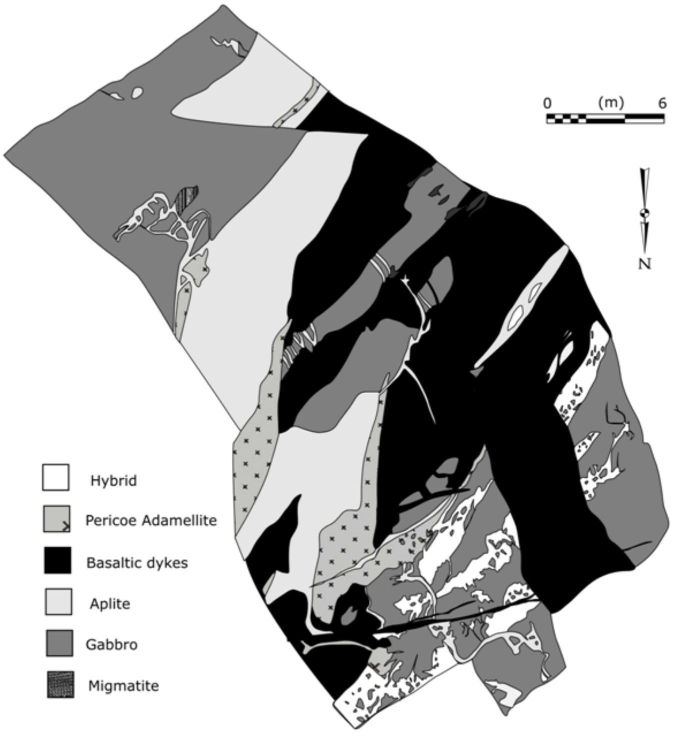
a) “Rip-up” clasts of basaltic fragments in different units. Photo also illustrates the sheeted or layered nature of the WWMC. b) Plume-like structure of felsic “diapir ” piercing through several layers. c) Entrapment of risine volatiles against an impermeable, chilled overlying mafic layer.

Stop 2 - Top of WWMC

Several km downstream from the "type locality", the upper contact of the WWMC is exposed (Figure 18). It consists of dyke-and sheet-Iike mafic bodies that are sub-concordant with bedding in migmatised, quartz-rich metasedimentary rocks. These metre-scale thick intrusives have amalgamated to form the gabbro complex, much like at the "type locality". Other similarities include chilled bases and rip-up clasts, and weakly-developed graded units. However, the major difference is the localised mixing and mingling with felsic material.

The uppermost 10 metres of the main WWMC unit consist of fine-to medium-grained, layered mafic rocks that are extensively intruded and partially hybridised with a fine microgranite (Figure 19b). This unit forms narrow discordant, curved (folded?) veins with local sharp contacts against the chilled gabbro, but elsewhere the contacts are diffuse and the rock is transitional to intermediate, heterogenous fine-grained hybrid rocks that are aligned concordantly with the gabbroic layers. The veins also contain small tine-grained (chilled) enclaves of gabbro. Elsewhere, larger mafic pillows are enclosed in granitic layers which are sub-concordant with the gabbroic sheets (Figure 19a).

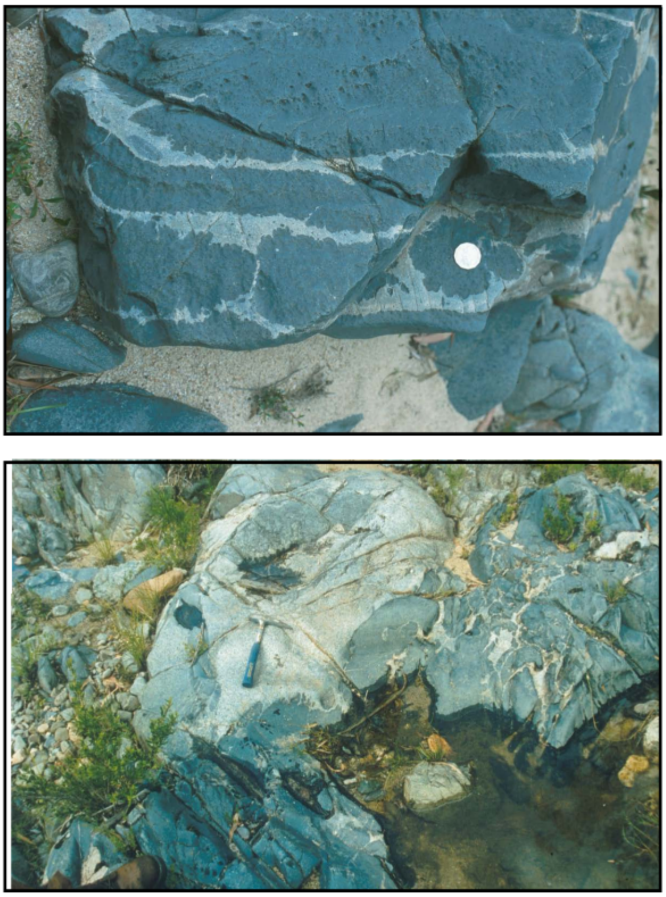
Figure 18. Map of rock-type relations at the top of the WWGC



Map of rock-type relations at the top of the WWGC.

At another locality, a south-trending network of granite veins rapidly diminish to tine stringers which spread E-W (laterally) against the overlying, fine-grained (chilled) mafic layer (Figure 19b). This layer appears to have been an impenetrable barrier to underlying, rising granitic melts. Thus, the granitic magma has intruded into the WWMC and hybridised along the less crystallised, more differentiated layers of the complex, indicating a coeval relation between mafic and silicic units at the top of the complex.

Figure 19ab. Rock detail



a) Vein network of granite enclosing “pillows” of medium - coarse grained gabbro. b) Chilled, crenulate contacts of Pericoe granite against WWGC.

Figure 19c.

c) Injection of leucosome in the sub-vertical axial plane of syn-migmatitic F3 folds. Injection of leucosome along S3 has isolated migmatitic blocks, forming diatexitic breccia.

Intrusive sheets and lenses of Pericoe and aplitic granite are also sub-concordant with the WWMC contact. Pericoe intrusions are typically lense-Iike, and commonly form a border between the migmatitic metasediments and WWMC. The aplitic veins generally post-date the Pericoe granite, as they contain rare fragments of the granite and locally cut granitic veins. However, some contacts between the two are gradational. Sharp contacts of Pericoe granite along the upper contact of the main WWMC, indicates that it generally post-dates solidification of the gabbro. However, in some places, pillow-like gabbroic WWMC enclaves within Pericoe granite, with either chilled on crenulate contacts (Figure 19b), show that the granitic and basaltic magmas were coeval, at least locally.

The last intrusive phase at this location is a 4-metre wide, discordant, N-trending, basaltic dyke which abruptly terminates in the quartzitic metasediments. A narrow stringer of the dyke continues southward for ~10 metres, but most stringers have propagated sub-parallel to bedding. This is an example of the transitional basalt dykes of Middle Devonian age, which cut the entire Bega Batholith. Similar dykes will be encountered downstream.

Several metres above the main contact, m-wide lenses of gabbro, up to 8 m long, are isolated within the migmatitic quartz-rich metasediments. These disrupted dykes are characterised by "pinch-and-swell" features, with the dykes "necking" within one metre to thicknesses of cm-scale. The lack of strong fabric development in the lenses or adjacent quartzites suggests that the "boudinage" occurred while the dykes were in the magmatic state, and the metasediments were migmatitic. Directly above the "boudinaged" dykes, a 2-3 m wide dyke/sheet of gabbro within the metasediments is broken in to angular blocks, separated by thin felsic veinlets of aplite, Pericoe granite and felsic hybrids. An unusual vein of coarse aplite, grading to pegmatite, cuts the dyke but also forms concordant pod-like structures, which appear to be small diapirs that have partly ascended through the overlying mafic magma. These appear to have been silicic melts that were present in the countryrock during the late stage stages of deformation.

Approximately 40 metres above the WWMC contact, the migmatised metasedimentary rocks are much more pelitic and exhibit markedly different character from their quartz-rich counterparts. Whereas the psammites occur as semi-concordant layers, the metapelite layers are broken into jumbled fragments within leucosome, and resemble a "breccia" (Figure 19c).

The leucosome appears to be originally K-feldspar and cordierite rich, but have been strongly retrogressed to muscovite-chlorite intergrowths. Locally, a narrow (mm-scale) halo of coarse mica rims the pelitic fragments. It resembles melanosome in regional migmatites, and could be a back-reaction product, implying that the water-rich, early melt phase did not escape from the site of partial melting. Alternatively, it is a reaction halo, suggesting that the pelite fragments are not in equilibrium with the leucosome, which was derived externally. Which alternative is correct?

Stop 3 – Disaggregated gabbroc ?dyke? in migmatite.

At this locality, a fine-grained granitic phase contains grey wisps and schlieren of a slightly more mafic phase. These granitic phases appear to be transitional between leucosomes of diatexite and microgranite dykes.

Across the river and several metres downstream are rounded to sub-angular blocks of gabbro in a diatexitic host. The gabbroic unit forms a sub-linear arrangement of disrupted blocks; the angular fragments are commonly rimmed by diatexite, but show little reaction with the host. In contrast, some more rounded mafic inclusions have diffuse contacts with the leucosomes and appear to have reacted with them to form localised hybrids. The rounded mafic inclusions may have been partly molten when juxtaposed with leucosomes, whereas the blocks appear to be part of a disrupted mafic dyke that predated, or formed during the early stages of migmatisation.

Stop 4 – Relationship between migmatites and felsic feeder dykes

Outcrops of migmatite and granite at the base of the Kameruka pluton (as shown in the lower Wog Wog River section) demonstrated that the migmatites generally predated injection of granitic magma; only some granitic sheets hybridised with the diatexites, indicating synchronous intrusion. This section investigates the relations of migmatites to the inferred feeder dykes of the Kameruka suite. Here, we focus on a well exposed felsic dyke that occurs below the base of the Kameruka pluton.

The syn-to late-migmatite timing of the felsic dykes can be inferred from contacts, which range from sharp to diffuse. Where the dyke shows sharp margins, it truncates the migmatitic fabric at low angles, suggesting fracture propagation through a rigid medium. However, within several metres the dyke margin becomes diffuse, suggesting that partially melted diatexite and granitic liquid interacted after propagation of that dyke. These diffuse margins consist of complexly folded veins emanating into the diatexite, and appear to contribute much of the leucocratic material of those diatexites. They become less defined away from the dyke margin and are commonly parallel or subparallel to the migmatitic fabric. Locally, larger apophyses of dyke material emanated into the leucosome, forming convoluted veins with contacts that are gradational to the leucosomes. In places, the leucosomes and microgranite cannot be distinguished, indicating that mixing of the two phases has occurred.

These microgranite dykes are weakly folded, with axial planes parallel to the main shallow-dipping flow foliation in the diatexite (which is regional S3). This relation indicates intrusion of the dykes late in D3 and coeval with the migmatisation event, consistent with the local cross-cutting contacts with the migmatites.

Stop 5 - Base of the Kameruka Pluton

This stop represents the same structural level as in the lower Wog Wog River (Day1 -Stop 2), where the sheeted nature of the Kameruka pluton is evident. A notable difference is the lack of abundant diatexite and granitic sheets. The basal contact is characterised by a narrow (15m wide) zone of leucocome-poor schlieren migmatites, some of which have hybridised with the granite. Hybridisation is characterised by the dispersal of Kameruka granodiorite xenocrysts throughout a finer grained diatexitic leucosome. Much of the structure of the migmatite is preserved within the hybrid zone with boudins of metasediment aligned parallel to flow-layering in the granite, defined by the crystal alignment of tabular plagioclase. This boudinage and crystal alignment suggests that hybridisation is shear related, as it is in the lower Wog Wog River. The paucity of leucosome at this location is considered to be significant. The presence of K-feldspar megacrysts in the diatexites indicates that much more leucosome must have been present to effectively hybridise and be dispersed throughout the migmatite. Thus, this zone possibly represents a site where leucosome has been removed from the migmatite, facilitated by compressive deformation during shearing. Migration of such leucosome material to higher levels could be represented by the diatexites that cut metatexites in shear zones or as accumulations in the axial planes of open folds (these are local F4 folds as discussed on Day 1).

Stop 6 - Kameruka–Basalt mixing

This dyke is flat-lying with irregular contacts, and as such, the boundaries are difficult to delineate. It is observed in the river as isolated, in situ outcrop among numerous transported granite boulders. The lower contact is a series of large, lobate, mafic enclaves with chilled bottoms, indicating "right way-up". The upper contact is a series of cm-scale, plagioclase-rich layers alternating with hornblende-rich layers, which locally form channel-structures and cross-beds. No detailed work has been carried out on this section so little is known about the absolute geometric and compositional relations.

This outcrop helps explain many of the charactistics of syn-magmatic mafic enclaves found in all Bega Batholith plutons but may also be applied to plutons worldwide. The most relevant feature for our purpose is the zone of interaction between gabbroic and crystal-rich Kameruka granite. There, cm-scale plagioclase and larger pseudomorphed K-feldspar grains (xenocrysts) from the Kameruka granite are dispersed through fine-grained gabbroic rock in wavy trails deformed by feldspar accumulations (Figure 20c). The trails range from clusters of feldspar to individual grains, all aligned parallel to each other, suggesting that it is a magmatic flow zone. Some of the trails emanate from larger clusters of feldspar resembling Kameruka granite, suggesting that granitic crystal mush and mafic magma co-existed in the same dyke.

Figure 20a. Mafic Enclaves

Cm-scale “mafic enclaves” interstitial to crystal-rich granitic mush.

Figure 20bc.

b) Mafic enclave in xenocryst-rich matrix within syn-plutonic dyke. c) Trails of pseudomorphous K-feldspar xenocrysts in hybrid dioritic matrix.

A less obvious mixing relation, but perhaps more important, is shown in Fig. 4.6.3. The rock is dominated by white feldspar, much of it pseudomorphed K-feldspar, aligned as a flow structure. The rock superficially resembles a granitic cumulate, but the matrix is fine grained mafic material rather than a felsic interstitial phase.

A few small mafic lenses resemble enclaves. The mafic material must have been a low viscosity liquid moving at relatively high flow rates to have permeated so effectively through the cumulate framework.

Commonly, small-scale "interstitial" mafic phases such as shown in Figure 20a are dispersed through granites. They are often overlooked because of their size, and perhaps because it is difficult to envisage how mafic material can permeate into and be dispersed through a granitic magma chamber. White and Chappell (1977) considered it to be restite, but the relations in Figure 20a is considered unequivocal evidence that basaltic magma and viscous crystal-rich granitic magma are capable of efficient mixing, but they have done so in a synplutonic dyke. Perhaps this is where efficient mixing occurs, but it is likely that subsequent flow of the hybrid dyke material into low viscosity granitic magma allow s for efficient dispersal through the chamber.

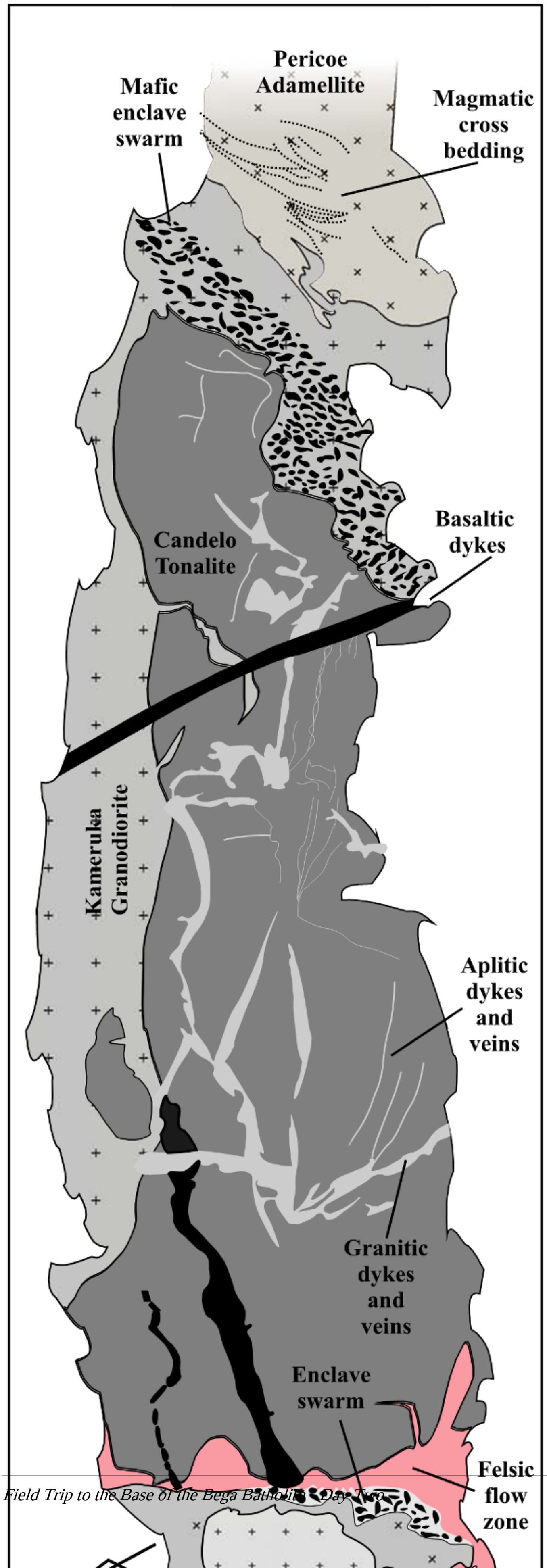
A final point from the outcrop: All the K-feldspar grains have been pseudomorphed by aggregates of sodic plagioclase and quartz, and are now xenocrysts in the synplutonic dykes. These xenocrysts, dispersed throughout fine-grained gabbroic material, closely resemble some of the xenocryst-rich hybrid zones found elsewhere in the Kameruka pluton. Does their presence in syn-plutonic dykes provide a general explanation for the origin of xenocryst-rich mafic enclaves? More evidence is presented at the next stop!

For a review on the mechanisms of enclave formation based in part on many of the outcrops we have visited see Collins, Richards, Healy and Ellison, 2000, Trans. Royal Soc. Edinburgh. 91 p 27-45.

Candelo xenolith

This site is possibly one of the most impressive stops of the trip. It represents a zone of accumulation of stoped rock fragments at the interface between the Kameruka and overlying Pericoe plutons. The fragments include metasediments, migmatites, tonalites, diorites and gabbros. The major feature is a large, approximately 120 x 80m xenolith of Candelo Tonalite suspended with in the surrounding Pericoe granite (Figure 21). Not only is this location unique in that the accumulation zone of stoped material is observed, but it can also be placed in stratigraphic context.

Figure 21. Simplified map of the Candelo Block (megaxenolith).



countryrock which has fallen (or slid) through the magma chamber (the Pericoe pluton) and come to rest on the floor of the pluton. The block is surrounded by unusual magmatic features which we believe formed during deposition of the large xenolith.

Pluton Structure

Unlike the highly variable Kameruka pluton, the Pericoe pluton is very homogeneous, has very few mafic enclaves and syn-magmatic mafic dykes, and lacks a magmatic foliation. The contact with the underlying Kameruka Granodiorite is characterised by a ~600m-thick zone of inter-sheeted granites from both pIutons, separated by a number of elongate metasedimentary screens. The zone also contains a complex array of mafic dykes, enclave swarms, metasedimentary xenoliths, highly variable hybrid granite types, and large fragments of granite and diorite. As all of these complex features exist at the base/ floor of the Pericoe pluton, it is an excellent example of an 'elephants graveyard', The presence of numerous Kameruka-Pericoe hybrids at the contact suggests a close temporal relation between the two plutons.

The Candelo Tonalite xenolith is located within the abovementioned contact zone, specifically at an interface between Kameruka and Pericoe granites (Figure 21). The tonalite is distinct from the two enclosing granites in that it is finer grained and much more mafic, containing abundant mafic enclaves and conspicuous hornblende grains. The tonalite also lacks the large K-feldspar crystals and rounded quartz grains that are typical of the other plutons. Three of the contacts have been mapped in detail, but the fourth is obscured by vegetation. All of the xenolith contacts are sharp, indicating that the tonalite must have been relatively rigid prior to its incorporation. Nonetheless, ductile shear zones in the tonalite suggest that it was able to deform plastically, and was therefore a semi-viscous block during emplacement. Several lines of evidence support this fragment representing a stoped block, including 1) sharp discordant contacts with host granites 2) angularity of contacts 3) truncation of mafic enclaves at the contact 4) truncation of a weak magmatic flow foliation within the tonalite 5) truncation of two mafic dykes within the block, at the contact 6) both Kameruka-and Pericoe-type dykes cut the tonalite 7) break-up of the tonalite into smaller fragments and incorporation into the host granite

An interesting and fascinating point to note is that the closest outcrop of Candelo Tonalite (in map view) lies some 30-40 km away! Pluton and batholith reconstructions must take this feature into account.

Cross Section through the Candelo Tonalite Megaxenolith

After walking through the base of the Pericoe pluton, a sharp bend in the river is approached. This signifies the beginning of an approximately 500m long section incorporating the Candelo Tonalite xenolith and the very unusual features associated with it.

Granites at the base of the Pericoe pluton are characterised by tabular euhedral plagioclase grains up to 2cm in length surrounded by sub-rounded quartz (I cm), interstitial biotite and small K-feldspar grains. Weak compositional layering, defined by slight variations in grainsize, is aligned approximately parallel to the E-W magmatic flow alignment of enclaves and tabular plagioclase.

Stop A.

The first stop is close to the base of a 15 x l0m gabbroic-diorite fragment surrounded by a tonalitic phase of the Pericoe pluton. The tonalite locally displays an intense foliation (Figure 22a), along the western contact (base) of the fragment (Figure 22a). We interpret the foliation as a compaction fabric caused by sinking of the diorite into a crystal-rich Pericoe mush.

Figure 22ab. Perico granite and felsic material

a) Strongly aligned fabric in Perico granite immediately below a large dioritic xenolith suggesting that the fabric is a compaction fabric. b) Flow zone of felsic material at the base of the Candelo megaxenolith.

Figure 22cd. Enclave swarm and Perico Pluton

c) Strongly aligned enclave swarm at the top of the megaxenolith. d) Cross-bedding in the Perico pluton. The rhythmic layering is defined by variations in biotite with the boundary between layers marked by an enrichment of biotite. A “package” of these layers may terminate at an angle to an overlying “package”. This geometry is similar to trough cross-bedding in sedimentary environments.

Stop B.

Approximately 50m downstream lies the contact between the base of the Candelo megaxenolith and a bounding flow-foliated zone of flow-banded felsic rock, grading to pegmatite (Figure 22b). Locally separating this zone from the underlying granodiorite is a variably flattened enclave swarm hosted in a narrow strip of Pericoe tonalite. The swarm is identical to that overlying the megaxenolith, and for this reason, we suggest that the huge block was emplaced within this (low viscosity?) feature. We can talk about the occurrence of these zones in the Pericoe pluton. Toward the center of the pluton, these enclave swarms are common and define a series of channels!

The felsic, flow-banded zone at the base of the tonalite has a distinct pink colour owing to the high proportion of K-feldspar. The rock itself varies from zones that are fine-grained and biotite-bearing to coarse-grained and biotite-free, which locally grade to pegmatite patches, which are concentrated near the contact with the tonalite xenolith. A very well developed, highly sinuous flow foliation is present throughout the zone, defined by biotite schlieren and zones of grainsize variation. The orientation of the foliation is variable yet sub-parallel to the megaxenolith, probably indicating that this zone was extremely fluid when formed.

We suggest that this "fluidised" felsic rock-type was a crystal-poor magma that originally defined the interface between crystal-rich and crystal-poor zones in the magma chamber. Locally, it can be followed into the underlying granite, as dykes. It resembles some of the layering in the Towamba River (Day 1, Stop 1), where we interpret felsic dykes to have entered the magma chamber. Thus, such felsic units probably represent original floor/chamber interfaces in the pluton, preserved as a result of an unusual disequilibrium process operating at the time. At this stop, we interpret disequilibrium to be fracturing of the underlying crystal-rich magma and ingress of the crystal-poor melt caused by collision of the tonalite megaxenolith onto the floor of the magma chamber.

Stop C.

Approximately 10m into the Candelo tonalite megaxenolith, a 2m wide mafic intermediate dyke can be followed 60m downstream (SE) where it terminates against the Kameruka granodiorite. Mingling features along the margin of the mafic dyke indicate that the dyke is late-plutonic in relation to the Candelo Tonalite. It indicates that the tonalite bock was rigid and intruded by dykes prior to fragmentation and incorporation into the base of the Pericoe pluton. This would be a perfect dyke to sample in order to determine the precise age of magmatism!

Stop D.

At this stop, an interconnected network of granitic dykes can be observed cutting the Candelo Tonalite. The dykes are connected to the surrounding Kameruka granite and vary from megacryst-rich through to aplite. The megacrystic dykes commonly display flow sorting highlighted by the accumulation of K-feldspar megacrysts along their margins. The dykes are commonly associated with small ductile shear zones. An example of shear movement can be seen where an aplitic dyke shows dextral offset along a cross cutting granite dyke. The interconnected network of dykes appears to represent a set of fractures that formed during the early stages of disaggregation of the large xenolith. Between Stops D and E, the proportion of felsic dykes and smaller veins increases dramatically, corresponding with increased proximity to the top of the xenolith. The dyking at this point forms a very complex array with no obvious preferred orientation. They probably represent "backveins" of host material, injected as the top of the megaxenolith began to fracture.

Stop E.

This site is located at the top of the Candelo tonalite, approximately 160m above the base of the xenolith. There, a mafic enclave swarm separates the top of the xenolith from the overlying Pericoe pluton (Figure 22c). The contact with the megaxenolith is sharp yet irregular and trends approximately E-W, then to N-S as it swings around the top of the megaxenolith. Embayments along the contact contain rounded to irregular enclaves, whereas salients contain highly stretched enclaves. Similar features are seen in the enclave swarm at the base. The longest axies of the enclaves form a steep east-plunging lineation. Overall, the degree of elongation decreases away from the xenolith. We interpret these features as indicating that the swarm was magmatic during emplacement of the rigid tonalite block. Enclaves that were localised in embayments around the block were protected from deformation, whereas the salients were most exposed and most deformed against the rigid block during emplacement. Nonetheless, the deformation was ductile rather than brittle, indicating that the host was largely magmatic, consistent with the top of the block having been emplaced into a melt-rich magma chamber.

Between stops E and F, the Kameruka granodiorite, which is in contact with the enclave swarm, grades into Pericoe Adamellite. There a series of compositional layers are preserved, with a structure that resembles sedimentary cross-beds.

Stop F.

Cross bedding in granites? Distinct compositional layers are apparent at this locality, some of which are extremely uniform in thickness (~15 cm), although variations exist. An enrichment of biotite at the base, together with fine-grained tabular plagioclase and a small amount of quartz define each individual layer. The biotite-rich zones grade progressively into biotite-poor zones at the top of each layer, which is enriched in euhedral to subhedral plagioclase, quartz and interstitial K-feldspar. The layers are curvi-planar and some are laterally continuous for at least 20m. The layers are parallel to one another and form sets containing between 10 and 30 layers. Each set of layers is delineated at low angles by other overlying sets (Figure 22d). The overall appearance of the zone is extremely similar to trough cross-bedding preserved in sedimentary environments. The cross-cutting relations between the sets indicates that younging and therefore, the top of the sequence is to the east, the same as that determined for the underlying Kameruka Granodiorite.

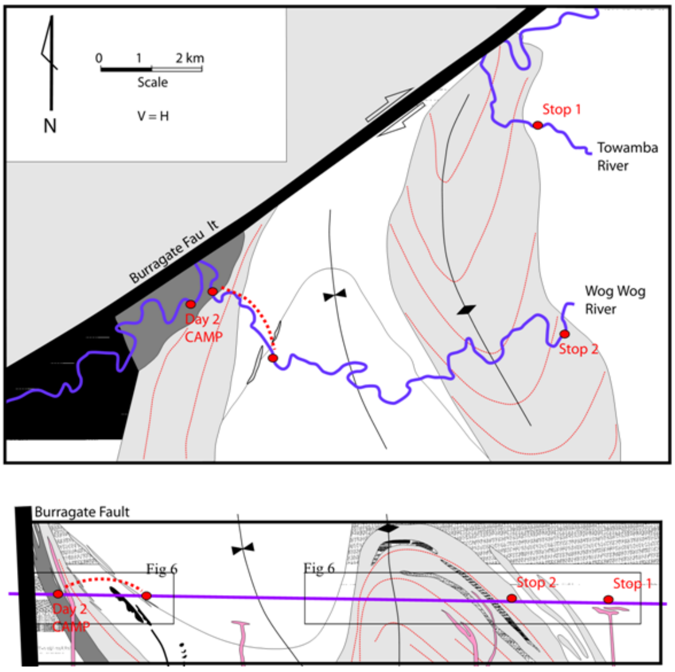
Formation of the Cross Bedding Structures

The similarity between the compositionally graded layers and features of graded bedding in sedimentary environments are suggestive of flow sorting by traction current activity. Similar processes have been proposed for other layered intrusion such as the olivine-pyroxene layering preserved within the ultramafic rocks of Duke Island (Irvine 1974, p15). However, in the Wog Wog River example, individual layers are defined by biotite and plagioclase concentrations. The layering is considered as the result of two main, interdependent processes: (1) fluctuations in the temperature of the magma initiated by the presence of the ?cold, tonalite xenolith, and (2) fluctuations in magma composition. Both of these processes may lead to the preferential nucleation and crystallisation of a specific mineral phase such as biotite. As the magma crystallises biotite, for example, the magma composition close to the crystallisation front changes, becoming depleted in elements required by biotite, forcing the crystallisation of felsic phases such as quartz and plagioclase. This continues until the magma returns to its initial composition, and a compositionally graded layer is formed. If the process is repeated, then the cycle is repeated and a type of rhythmic layering is produced. This is one of many possibilities such as flow sorting and crystal settling/accumulation, but has yet to be proven for the Wog Wog example. Generation of the cross-beds requires a different process. As mentioned above, the cross beds are structured/ordered in a similar fashion to trough cross bedding observed in sedimentary environments where currents are present. It is envisaged that while the layers are chemically controlled, the cross beds formed by scouring due to current movement or magma flow, causing erosion of the earlier formed layers. This scouring and development of traction currents is extremely unusual may have resulted from the emplacement of an unusually large block (megaxenolith) of solid material into a crystal-poor magma chamber containing only plagioclase and biotite as cumulus minerals.

Interpretation of Megaxenolith Emplacement

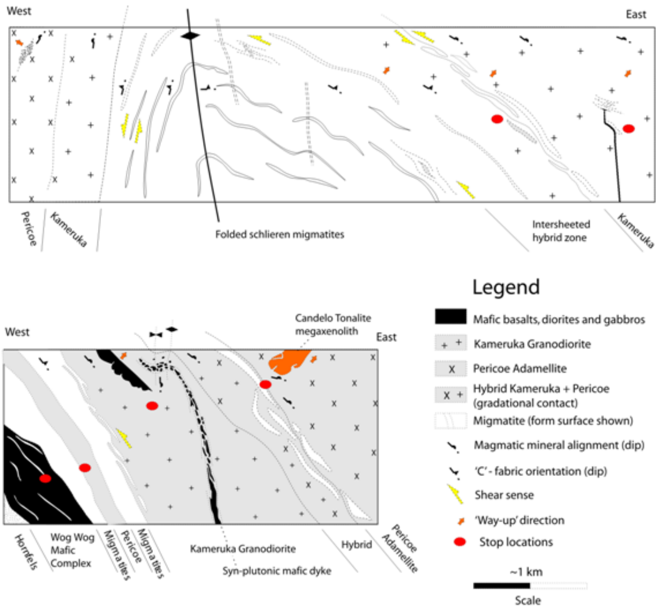
The evidence discussed above indicates that the Candelo Tonalite is a large xenolith that was rigid and capable of fracturing during emplacement at the base of the Pericoe pluton. Several interpretations have been made concerning the development of the features surrounding the megaxenolith, and of which relate back to the position of the xenolith at the base of the pluton and the mechanism by which it was deposited/incorporated. The Pericoe pluton is basin-shaped and lies in the inverted saddle of a megascopic south-plunging synform (Figure 2 and Figure 6 X-section). The eastern contact dips steeply to the southwest whereas the western contact, where the xenolith is located, dips moderately to the south east. The xenolith can therefore be considered as being located on the shallow, e-tilted floor of the pluton, and is interpreted as a large stoped block of overlying Candelo pluton that has sunk through the Pericoe pluton coming to rest on the pluton floor. Candelo Suite granites are the earliest emplaced pluton in the Bega Batholith, followed by syntectonic intrusion of Kameruka Granodiorite and, soon after, by the Pericoe pluton. The latter was emplaced into the regional synform that was produced by syn-plutonic compressive deformation. Country-rock along the upper contact of the Pericoe pluton must have included solidified Candelo Tonalite, a large fragment of which as was stoped off and sunk through the less dense, partially crystalline magma chamber. Other stoped material included migmatites and gabbroic bodies.

Figure 2. Map and location of stops visited on this trip



The cross section gives a general overview of the structure of this part of the pluton. Apparent ‘folding’ of the pluton has resulted in exposure of the base of the pluton in a number of localities, two of which we shall be visiting.

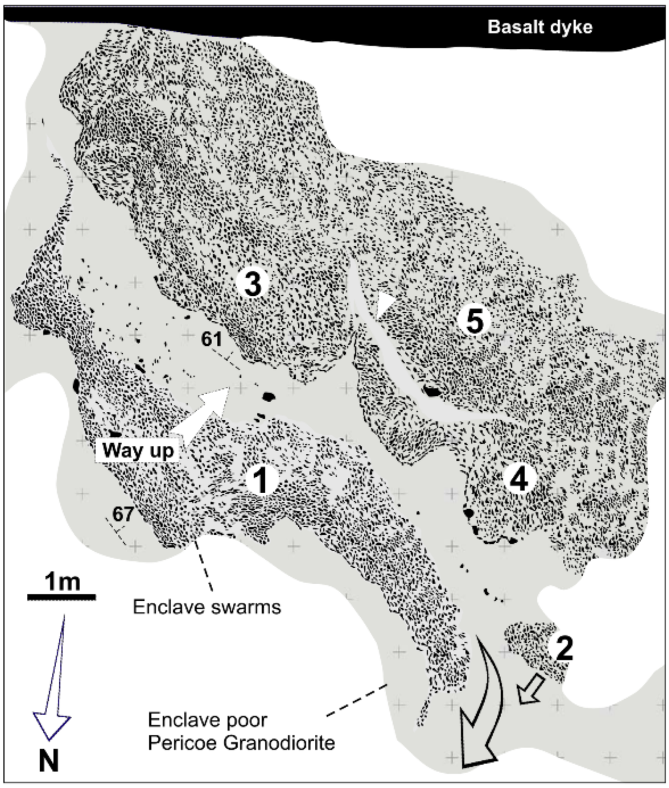
Figure 6. Characteristic Features



Details of some of the characteristic features we will be observing on this trip. The top cross-section is applicable to stops on the first day in the Towamba River and Lower Wog Wog River. The lower cross section shows features observed on the second day in the upper Wog Wog River.

These may have been stoped at the same time, or represent blocks accumulated over a period of time. The latter interpretation is supported by the presence of blocks at various levels of the 600m thick zone. If so, it is an excellent example of an "elephants graveyard", the postulated zone of deposition of large stoped blocks at the base of plutons. The base of the pluton at this time was also accumulating a layer of mafic enclaves, possibly representing a MASLI-type deposit. As the megaxenolith collided with the bottom of the chamber, it disrupted the MASLI layer and formed a trap for escaping volatiles and felsic liquids which ponded beneath it. Presumably, the megaxenolith then rotated into a position of repose, resulting in the formation of unusual convection currents in the directly overlying magma chamber. The thermal disturbance and turbulence in the magma chamber, generated by sinking and settling of the xenolith, resulted in the formation of the overlying compositionally layered granite, which was disturbed and redeposited as 'cross bedding'.

Figure 23. Additional Figure



We will not have time to visit this spectacular outcrop, however, it is worthy of a short discussion. The site lies some 800m downstream and sits within the Pericoe pluton. Here enclaves have accumulated in a number of cresent-shaped ‘lenses’. This figure shows only a small portion of these enclave swarms. The lenses have arcuate, concave upwards shapes which are defined by a dense accumulation of emclaves. Here the enclaves are closely packed and mould around underlying enclaves and exhibit classic ‘pillow’ shapes. Away from the contact (toward the southwest) the enclaves become dispersed into the overlying granite. We have interpreted these structures as enclave-rich channels where mafic material (enclaves) have come to rest on a crystal-mush boundary within the pluton. Classic MASLI type structures. Successive deposits overly previous accumulations so that the channels appear stacked; oldest at the base, youngest at the top. These features closely resemble a cross-section through an aggrading valley floor deposit.

References

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