092H/05
Seneca

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MINNOVA INC.

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TO: Colin Burge

COPIES TO: Ian Pirie

FROM: John Bradford

SUBJECT: Geology of the Seneca Property

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1. Stratigraphy

Discussion of Seneca stratigraphy is in two parts, Seneca proper and "Vent", because of the way the two grids were set up and because stratigraphic ties between the two areas are somewhat tenuous. The stratigraphic setting of mineralization is included in the discussion.

A. Seneca Area

The volcanic stratigraphy of the Seneca area can be divided into three generalized units, a lower sedimentary-felsic volcanic interval (known as the "Trough"), a middle felsic dome-volcaniclastic sequence, and an upper mafic to intermediate volcanic unit. The Seneca deposit is interpreted as a transported VMS and lies within the lower part of the upper unit. The entire sequence is intruded by felsic porphyry dykes which probably feed thick flows of similar composition above Seneca.

1. Trough Sediments and Felsic Volcanics

The Trough sequence outcrops in a low area (below 200 metres elevation) along and south of the main road and in the creek just north and east of the road. Most information about the sequence is derived from 1979 drill holes by Chevron. The sequence seen in these holes consists of a lower crystal and pumice - rich ash flow tuff, overlain by a mineralized felsic flow - dome and an upper epiclastic sedimentary unit (Figure 1). Outcrops indicate this sequence dips to the east at 10-15°.

(a) Ash Flow Tuff - An ash flow unit at least 60 metres thick is intersected in DDH 79-10 and 79-18. It consists of 10-20% green chloritic fiamme and feldspar porphyry lithic fragments in a crystal and ash matrix (Baxter logs). It appears to be partly welded. It is unclear whether this is a subaerial or waterlain unit; if the former, deposition of overlying waterlain sediments implies a subsidence or caldera collapse event following deposition of the ash flow.

(b) Felsic Flow-dome - A dacitic to rhyolitic flow-dome overlies the ash flow unit above an interval of epiclastic sediments and ash and crystal tuff (e.g. DDH 79-10, 78-91 metres). Emplacement of the flow therefore postdates the onset of the subsidence event. The unit thins and probably pinches out from west to east, with intersections of > 100 metres in DDH 79-12, > 48 metres in 79-22, and 15-20 metres in 79-10 and 79-18. The thicker part of the unit to the west may be intrusive. Brecciated tops and bases are noted by Baxter in the thinner parts of the flow. Disseminated and stringer sphalerite - chalcopyrite occurs throughout the bleached and silicified unit, with coarse vuggy sphalerite in at least one vein. Samples from an outcrop by "Stinking Pond" contained up to 2289 ppm zinc. No sodium depletion is evident.

(c) Sediments and Tuffs - The sediments which for the most part overlie the felsic flow include interbedded argillite, ash tuff, greywackes and one or more distinctive well bedded crystal tuff horizons. Outcrops are scattered and widespread, making internal correlation difficult. Thin bedded A-E turbidites with arkosic sandstone are interbedded with 0.5 metre thick felsic ash beds in a creek north of the powerline (stn. 126); this appears to grade laterally into bedded crystal tuff. Interbedded, medium bedded pebble conglomerate/greywacke and black argillite outcrops along the main road, with basal load features and normal grading indicating tops up. In one outcrop south of the powerline (between lines 3 and 4 E), similar wackes and grits overlie a quartz phyric ash flow tuff similar to unit (a).

Argillites outcrop along the main road near line 4E and near Stinking Pond; these are weakly anomalous in barium (261 ppm), probably reflecting widespread exhalative activity during sediment deposition. Ash tuffs in the creek below the main road (just north of T.L 10 S) are anomalous in zinc (230 ppm) and lead (93 ppm).

Generally well bedded, thin bedded to laminated crystal tuff is typical of the Trough sequence, and is used as a stratigraphic marker from the Trough northwest toward the "Vent Zone". The unit is similar to air fall crystal tuffs described in, e.g. the Hazelton Group, but may in fact be waterlain, given its associated sediments. It is rhyodacitic to rhyolitic in composition, and consists mainly of feldspar crystals and pale green to white ash. Variable minor components include quartz crystals, pumice fiamme and thin argillite lenses. Spherulites are present locally.

Exhalative mineralization is associated with pyritic laminated mudstones in Trough drill holes. An outcrop at 0+80 N, 2+20 W (stn. 58) contains similar mudstones, which run 731 ppm zinc (SJ90-034). These underly the crystal tuff marker, and are correlated with the Trough sequence.

(d) DDH'3 73-29, 75-42 - Trough - type sedimentary strata are intersected in three Seneca drill holes, 83-1, 73-29 and 75-42. Deep drilling in 83-1 intersected Trough sediments at about 100 metres elevation, consistent with the projected elevation from the

Trough area, assuming gentle dips. Both 73-29 and 75-42, two of the southeasternmost Seneca drill holes, were collared very close to similar sedimentary/epiclastic strata, at about 260 metres elevation. In 73-29, these underlie dacitic lapilli tuff similar to that overlying the felsic dome in the middle dome-volcaniclastic sequence. Apparently the sequence intersected just north of 42 in DDH 74-34 is not correlatable (C.B.), despite containing some similar lithologies (ash tuff, crystal - lithic ash-flow tuff). Occurrence of apparent Trough correlatives at this elevation is a stratigraphic enigma at present, resolvable only by tight block faulting (bringing Trough stratigraphy up) or a significant facies change.

2. Seneca Felsic Dome and Volcaniclastics

(a) Dacite to rhyolite flow-dome - Outcropping in cliffs above the main Seneca road and the Trough sequence is a feldspar phyric, dacite to rhyolite dome or composite flow. To the northwest this unit abuts against a synvolcanic fault bounding the main Seneca deposit (the "Seneca fault", below), while to the southeast it appears to pinch out within mainly volcaniclastic rocks. The base of this flow-dome complex overlies Trough sediments, which appear to pinch out to the northwest (near Stinking Pond) between the thickening Trough flow and the overlying Seneca flow-dome. The latter is widely but weakly altered, with patchy bleaching, silicification and disseminated sulphides. Weak silica-sulphide stockworks occur locally (e.g. SJ90-054). Breccia textures are common in weathered outcrop surfaces. Screens of dacite lapilli tuff (map unit 3.8) mapped within the complex may in fact be strongly autobrecciated flows. Hornblende - phyric, pyritic rocks occurring within the upper part of the complex were mapped as intrusives (6.2), but could be flow units as well.

Lithogeochemistry shows widespread low-level zinc and barium anomalies (to 434 ppm zinc, 241 ppm barium). Pervasively fractured, silicified and pyritized lapilli tuff immediately above the dome contained 747 ppm zinc, 277 ppm copper (SJ90-025). This widespread disseminated mineralization may be responsible in part for the large soil anomaly downslope from Seneca. No sodium depletions are evident.

(b) Dacitic heterolithic lapilli tuff - Overlying the dome is a poorly sorted, locally poorly bedded heterolithic lapilli tuff of dacitic bulk composition. The dome/tuff contact is intersected in a few holes (e.g. 85-5, 6 and 7), with shutdown occurring in disseminated to stockwork mineralization in the underlying dome. Otherwise, most Seneca holes were shut down in lapilli tuff.

The bulk of the clasts are feldspar phyric dacite, similar to the underlying dome; some darker green andesitic clasts are present as well. Locally the unit grades into finer tuff with scattered lapilli and thin beds of vesicular crystal tuff. Argillaceous horizons occur locally, and pumice fragments are common near the top.

The unit appears to decrease in thickness from northwest to southeast, perhaps pinching out over the top of the dome, which may have intruded its overlying tuff mantle. It appears to thicken on the northwest side of the Seneca fault mentioned above, with thicknesses of 50 metres in DDH 75-38 and >100 metres in DDH 73-27. The dome appears to be absent on this side of the fault, and lapilli tuff overlies Trough - correlative sediments and crystal tuff.

(c) Adit feldspar porphyry - A small, irregular body of feldspar porphyry dacite outcrops about 100 metres west of the pit within the lapilli tuff unit. The Seneca adit is collared in this body.

1+75W

Near B.L., 0+75 W, it is intensely silicified, with vuggy quartz veins and sphalerite-pyrite stringers. This may be the surface expression of vein mineralization mined in 1969. A similar intrusion outcrops near DDH 83-14, where it is intensely bleached and and silicified, with 5-10% disseminated pyrite and sphalerite veinlets. This body is truncated by later, unaltered dykes to the northwest. These bodies are separated from the underlying dome (at least on surface) by the lapilli tuff mantle. It is possible that they represent a late, resurgent, intrusive phase of the dome.

3. <u>Seneca Mafic to Intermediate Volcanics and Epiclastics</u>

Stratigraphy above the middle unit is best seen in the immediate pit area, as it is disrupted by intrusions to the southeast and offset by a fault to the northwest. Stratigraphy of the upper unit consists of a lower thin argillaceous horizon, overlain by mafic flows and then andesitic tuffs (Figure 1). Southwest of the pit are scattered outcrops of amygdaloidal (chlorite - calcite - pyrite), feldspar and hornblende phyric andesite. A contact with dacite lapilli tuff in the creek draining the pit is sheared, dipping moderately to the northeast. This is probably a dyke.

(a) Argillite - A hiatus between felsic and mafic volcanism is marked by an argillaceous horizon overlying the dacite tuffs. The argillite contains pyritic laminae. A tramsitional unit of argillite with feldspar crystals and/or porphyritic fiamme (Garrett's "footwall marker") occurs at the base of the argillite. The argillite outcrops near 2 S, 2 E (stn. 15), where it is associated with a pyritic cherty exhalite. Mineralized felsic dome fragments can be seen in laminated pyritic mudstones, linking possible dome resurgence and exhalative activity. The cherty exhalite runs 8188 ppm zinc, with the pyritic mudstone running 1657 ppm zinc.

(b) Basalt flows - The immediate hosts for Seneca mineralization are massive and fragmental amygdaloidal basalt flows (49-50% SiO_2, 0.85% TiO_2) and flow breccia. In the pit area these enclose lenses of fragmental material ("ore zone conglomerate") and argillite, which are bounded by steeply to shallowly dipping shears. Locally, argillite is interstitial to basalt blocks. Basalts throughout the pit area are visibly unaltered other than minor disseminated pyrite, and no sodium depletion is evident.

(c) Ore Zone Conglomerate - Several small lenses of fragmental felsic volcanics, massive sulphide and barite occur in and near the pit, and in numerous drill holes. Clasts are similar in composition to those in the dacite lapilli tuffs, but are generally more rounded, sand to pebble sized, and matrix is generally pyrite rich. The conglomerate varies widely in thickness, and grade is highly variable, depending on occurrence of massive sulphide blocks.

The ore zone conglomerate is probably derived from the erosion of the dacite lapilli tuff and a massive sulphide body at the stratigraphic interval at the base of the upper unit. Reasons include:

(1) clasts in the conglomerate are identical to those in the lapilli tuff,

(2) lack of alteration in the host basalts indicates that mineralization preceded basalt deposition,

(3) the most likely interval for syngenetic sulphide deposition is the hiatus between felsic and mafic volcanism, which is known to include exhalative sulphides in the Seneca area, as described above.

The source direction of the massive sulphide body is debatable. In long section, the dacite lapilli tuff is clearly fault offset on the order of 100 metres, south side down, about 100 metres northwest of the pit (Seneca fault). The fault, projected to the northeast, fails to offset later felsic intrusives, and is therefore probably synvolcanic. Ore zone conglomerate clasts could have been derived from fault blocks to the northwest, transported into the downfaulted basalt/argillite - filled basin. Faulting continued during erosion, as a mineralized conglomerate outcrops above the Seneca core shack, on the uplifted side of the fault. Interpretation of stratigraphy in the Vent area makes the Vent dome approximately time-correlative with the middle Seneca unit (it postdates Trough - equivalent ash tuff); it is therefore a strong candidate for the feeder system for a VMS body at the top of the felsic interval. Later compression remobilized the conglomerate lenses along small-scale thrusts or shears, as seen in the pit.

(e) Intermediate Tuffs - Immediately overlying basalt flows in the pit area is a sequence of andesitic tuffs. The lower part of the tuff sequence consists of andesitic lapilli tuff (63% SiO_2, 0.75% TiO_2) with amygdaloidal (chlorite - calcite) clasts and distinctive, dark green feldspar phyric fiamme, the notorious "hangingwall marker" of Garrett. This is overlain by finer bedded tuffs, including cherty ashes, crystal - lithic lapilli tuff with < 1 cm glass shards, and locally cross-bedded laminated ash and crystal tuffs. Argillites are seen in drill core within this interval. Fine tuffs outcrop discontinuously to the southeast to large exposures near DDH 74-31 and isolated exposures as far as 7 E, 4+50 S.

Mafic to intermediate flows and tuffs overlie the ash horizon. These are mainly amygdaloidal massive flows as seen, e.g., near B.L., 3-4 E. Intercalated lapilli tuff to tuff breccia, locally with thin ash lenses, are exposed, e.g., on cliffs at 550 metres elevation, lines 4-5 E. This sequence also contains rare feldspar porphyry dacite clasts.

B. Vent Area

(a) Vent Ash and Crystal Tuff - Understanding of Vent geology is limited by large overburden covered areas and widely scattered drill holes, except for the cluster of short holes in the Vent dome. The only stratigraphic link between Vent and Seneca is the Trough bedded crystal tuff unit, which underlies dacite lapilli tuff immediately north of the Seneca fault. It appears to continue at the same elevation to the northwest, outcropping on the Upper Fleetwood Road near Lomar and Gamble Creeks. Here, however, the mudstone/exhalite is absent, and the crystal tuffs are intercalated with ash tuff, minor tuffaceous sandstone, and amygdaloidal andesite. The andesite is a tuff breccia or flow breccia, with amygdaloidal clasts in a fine andesitic matrix. Amygdals are replaced by sphalerite and chalcopyrite locally, and epidote clots and amygdals are common. Further projection of the crystal tuff unit to the northwest is unclear because of lack of outcrop, but a mottled ash and crystal tuff near Hogan Creek on the Slash Road and intersected in DDH 86-7,18 and 19 may be correlative.

Similar ash tuff and intercalated crystal tuffs occur near the junction of Floyd and Gamble Creeks at 160 metres elevation, and felsic ashes outcrop in Blonde Creek at the same elevation. These may represent the same sequence dipping downhill (a dip of about 18° SW would be required).

(b) Vent Pyroclastics - Scattered outcrops of felsic to andesitic pyroclastics occur near 104-105 E below the Lower Fleetwood Road, overlying ash tuffs in Blonde Creek. If the ash tuffs are the down-dip projection of Trough equivalent ashes outcropping on the Upper

Fleetwood road, then the pyroclastics overlie Trough stratigraphy.

Vent pyroclastics include minor amounts of heterolithic lapilli tuff interspersed in coarse, vent proximal breccias consisting primarily of dome material. These include altered, greenish feldspar porphyry rhyolite and ribby, flow-banded rhyolite in a white siliceous ash and crystal matrix. Clast outlines are commonly vague as though altered with the matrix in a hot, compacting pile.

A distinctive andesitic unit occurs within this sequence, and can be traced across the Vent dome to Charlie Creek (line 97) and S2 Creek (line 93). This consists of dark green chloritic andesitic tuff containing poorly sorted lapilli and bombs of pinkish felsic domal material. Frothy rhyolite pumice occurs in places. The matrix averages about 52% SiO_2, 0.68% TiO_2, and commonly contains disseminated and stringer pyrite, sphalerite and chalcopyrite. Felsic material includes epidote altered feldspar porphyry bombs with cauliflower surfaces and amygdaloidal (epidote - quartz - chlorite) interiors. These are typical steam explosion features. A sampled bomb (SJ90-205) was not sodium depleted. The bombs may represent a precursor to the Vent dome which blew up during an interval of more distal andesite tuff deposition.

From outcrops in lower Hogan Creek, the andesitic unit trends northwest to below the Lower Vent occurence, where it is intersected in DDH 86-24 and 86-13 at about 160-170 metres and appears to be flat lying. It is offset by a fault (partly occupied by a QFP dyke) immediately northwest of the Lower Vent, occurring about 20 metres elevation higher up the hill. An intersection near the top of 86-23 at about 255 metres elevation represents the fault offset continuation from 86-13, with an intervening dyke or dykes again occupying the fault. Outcrops in Charlie Creek at about 245 metres elevation are the down-dip projection of this intersection, assuming that dips are shallow to the southwest. The unit again outcrops between 260-275 metres elevation in S2 Creek; no fault offset is required between here and Charlie Creek with a shallow southwest dip.

The andesite pyroclastics are aparently intruded by the Vent dome (see below); widespread epigenetic mineralization within this unit could therefore be related to the dome. It appears to have offered a more permeable horizon for dome - related hydrothermal fluids than the felsic pyroclastics.

(c) Vent Dome - The Vent dome outcrops near line 100 E from 140 to 255 metres elevation, and continues beneath overburden to at least 101 E, 2 N. It is also intersected at depth in DDH 87-2. It is cut on its northwest side by dykes which intrude along faults. The dome overlies andesitic pyroclastics southeast of the faults (e.g. DDH 86-13), and underlies them on the northwest side (DDH 86-23, 86-18), given that the correlations in (b) are correct, and the pyroclastics overlie the ash tuffs. This implies that faulting preceded dome emplacement, and that the dome is intrusive into the ash - coarse pyroclastic pile (Figure 2). It is unclear whether there is also an extrusive component to the dome. Using the Trough - equivalent ash as a time horizon, this makes the Vent dome essentially coeval with the middle Seneca unit.

The dome is intensely altered to a quartz - sericite - pyrite assemblage, with feldspar phenocrysts and matrix completely replaced by quartz and sericite. Thirteen lithogeochemical samples show strong Na_2O and CaO depletions relative to all other felsic rocks in the area. K_2O, MgO and locally, barium are enriched. Stockwork sphalerite - chalcopyrite mineralization outcrops over a vertical extent of 100 metres, with the zone broadening with increasing elevation. Stockwork generally follows the edge of the inferred faults.

(d) Northwest of Vent - Sporadic outcrops make interpretation of geology northwest of Vent speculative. A felsic ash horizon outcrops in S2 Creek above and below the Lower Fleetwood road, and in Slim Creek to the southeast. Correlation of these exposures is consistent with the shallow to moderate southwesterly dips observed, although exposures are truncated by dykes. The andesitic pyroclastic unit in S2 Creek above the Upper Fleetwood Road overlies the ash tuff, as indicated above. The tuff locally contains pyritic, siliceous beds which are weakly anomalous in copper (106 ppm) and zinc (198 ppm: SJ90-090, 091).

The ash tuff unit probably correlates with similar ashes in DDH 87-10 and 12; correlation with the Trough equivalent (?) horizon in DDH 86-18 and 19 is also possible, but more drill information is needed to confirm this. The ashes overlie the massive and stockwork sulphide mineralization in DDH 87-12. If the altered flow-dome in 87-12 is the lateral equivalent to the Vent dome, the correlation of ash tuff exposures implies that the dome is intrusive in 87-12 and that sulphide mineralization above the dome is a replacement rather than a true exhalite. Alternatively, it may be an earlier flow, coeval with the mineralized Trough flow.

Northwest of 87-10 are scattered outcrops of felsic flows and pyroclastics. A cherty exhalite horizon outcrops near 90 E, 3+75 S, near a zone of intense silica - pyrite alteration of andesitic volcanics. No anomalous values were returned from this zone (SJ90-195, 196, 198).

2. <u>Intrusive Rocks</u>

(a) Dykes - Feldspar porphyry is the most common rock type at Seneca. Pearson (Geology, Exploration and Mining, 1973) was the first to identify the FP's as dykes which "tend to block out potential areas of ore location". They include feldspar porphyry, feldspar - hornblende porphyry, and quartz - feldspar porphyry, ranging in composition from dacite to rhyolite. Colnmnar joints are common, generally plunging shallowly to the southeast. Hornblende bearing dykes are magnetic, and commonly contain small dioritic xenoliths. They appear to trend northwesterly for the most part, dipping steeply to the northeast.

Mafic dykes are also common, but are volumetrically less abundant. Some may be feeders to the mafic flows in the upper Seneca package.

A relatively thick amygdaloidal feldspar hornblende porphyry of andesitic composition outcrops southeast of the pit. Shallowly plunging columnar joints indicate an intrusive origin, while a steep dip is consistent with sections. Very similar - looking rocks on strike to the southeast are dacitic in composition.

(b) Quartz - feldspar porphyry - An extensive body of QFP rhyolite outcrops in the northwest corner of the Seneca grid. This unit is very weakly altered, and contains coarse feldspar and quartz phenocrysts. Its outcrop extent suggests that it may be a plug, and may represent a late phase intrusion at the core of the Seneca volcanic edifice.

3. **Structure and Metamorphism**

The Seneca property seems to be structurally simple. No penetrative deformation is evident, and dips are flat to moderate. Stratigraphic interpretation and limited bedding measurements indicate that dips change from flat to shallow northeasterly in the Seneca area to shallow to moderate westerly dips around the Vent. Evidence indicates that the two identified northeast to east trending fault structures on the property, the Seneca fault and the

Vent dome faults, are synvolcanic. Good drill control in the Seneca area shows that minor fault offsets (20 metres or less) have uplifted stratigraphy northeast of the pit. The offsets probably occur along northwest trending, steeply northeast dipping dyke contacts; if so, reverse movement and a compressional origin is indicated. Shearing along mafic - sediment contacts near the pit may be evidence for small scale thrusts within this unit.

Widespread epidotization affects andesitic rocks in the Vent area, and is probably hydrothermal. Seneca rocks have undergone zeolite grade metamorphism. Intensity of zeolitization increases to the east and northeast. Seeing through the zeolite overprint can be very difficult in places, as weathering results in poor, crumbly exposures. Chevron geologists mapped intensely zeolitized rocks as a separate unit ("Dlg" or "rottenstone"); however, this results in grouping together, e.g., mafic volcanics and felsic intrusives. In some cases, though, the rock type can only be guessed at.

4. Exploration Potential

The geological interpretation resulting from the 1990 mapping program has the following implications for exploration on the Seneca property and beyond in the Harrison Lake Formation.

(1) The Seneca deposit is transported from a rich massive sulphide body which probably formed in the transitional interval between the middle and upper Seneca units. The Vent dome could also belong to this period, given that it is intrusive into Trough time-equivalent ash tuffs and overlying pyroclastics. Accordingly, the in situ source of Seneca could have been in an uplifted fault block

to the northwest, and the unexplored continuation of the transitional interval lies at higher elevations northeast of the Vent grid. The felsic - mafic transition could represent a key horizon for regional exploration elsewhere in the belt.

(2) An earlier mineralizing episode is represented by low - grade exhalite in the Trough and its underlying mineralized flow/dome. Near - ore grade mineralization in DDH 87-12 may be correlative, and is open in all directions. Exploration potential of this horizon to the northwest is unlimited, and further mapping and eventual drilling in this direction is warranted.

(3) As far as I know, no significant mineralization postdates the onset of mafic volcanism; the existence of the transported Seneca orebody within this interval is a red herring. Mafic stratigraphy within the belt would therefore represent a low priority.

(4) The felsic intrusions represent a major impediment to exploration, and have the potential to kill a discovery at the drill definition stage. Regional exploration in the belt should take this into account, and give enhanced priority to any areas that lack large volumes of unaltered porphyry. Since the dykes are positive topographic features, poorly outcropping areas could be significant.

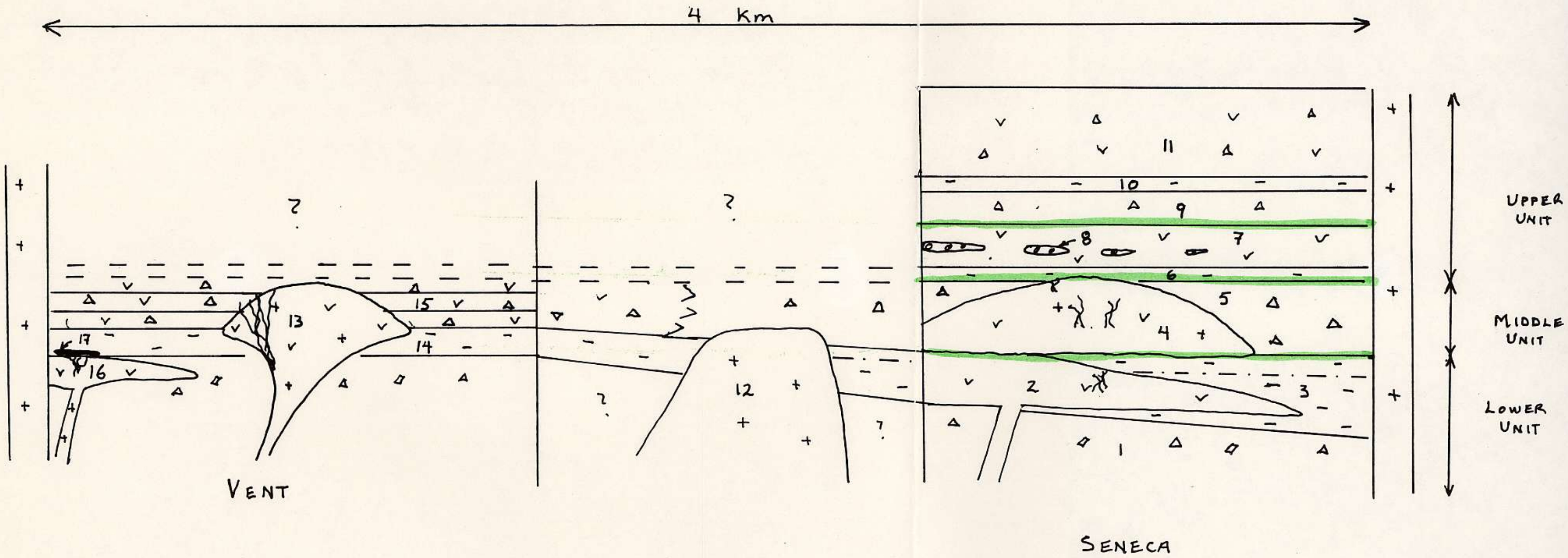

Figure 1: Schematic Seneca stratigraphy. 1 - ash flow tuff, 2 - felsic flow, 3 - Trough sediments and tuff, 4 - felsic dome, 5 - felsic lapilli tuff, 6 - argillite, 7 - basalt flows, 8 - ore zone conglomerate, 9 - andesite lapilli tuff, 10 - ash tuff, 11 - andesite flows and tuff, 12 - QFP, 13 - Vent dome, 14 - ash tuff, 15 - pyroclastics, 16 - felsic flow/dome, 17 - 87-12 sulphides.

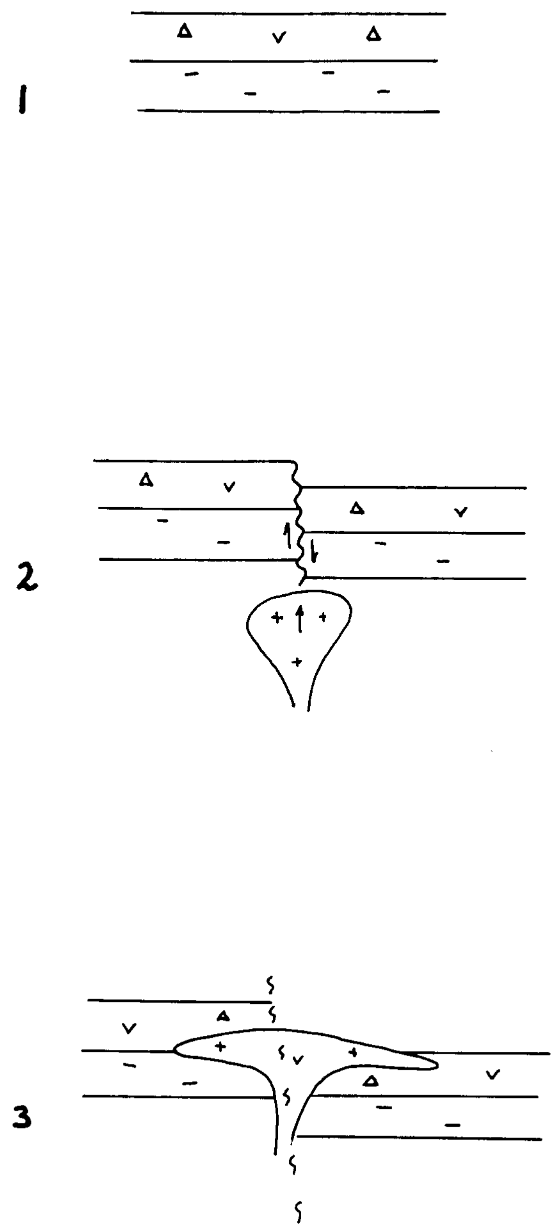

Figure 2: Timing of faulting and intrusion of Vent dome.