# Summary report on lode platinum exploration, Goodnews Bay, Alaska.

**W. I. Van der Poel**
Consultant, 510 Dickinson, Missoula, MT 59802 406-728-1861

**T. K. Hinderman**
Alaska Earth Sciences, 11341 Olive Lane, Anchorage, AK 99515 907-522-4664

## ABSTRACT

**Two Alaska-type zoned ultramafic intrusives, located south of Goodnews Bay in southwest Alaska, were the sources for more than 20.2 tonnes (650,000 ounces) of placer platinum. Both geochemical and geophysical data indicate that processes within the Red and Susie Mountain complexes may have concentrated platinum group elements (PGEs) to grades that are economic for lode mineralization. Several significant soil-geochemical platinum anomalies have been identified at both Red and Susie Mountains, and at Red Mountain, magnetic, gravity and resistivity data provide insights into the deep structure which suggest targets for drilling.**

**At Red Mountain, aeromagnetic data show radial and concentric patterns which resemble diapiric fracture systems and which partially coincide with platinum concentrations in soil. In addition, remanent magnetic data reveal zones of reversed polarity indicating at least two intrusive events. Bouguer gravity values are significantly elevated under the south end of the complex and southern portions of the Border Zone, suggesting that deep feeder structures or roots may underlie those areas. CSAMT data show resistivity lows at depth within the Border Zone and in a gently-dipping interface of relatively low resistivity which may lie within the complex or at its base. Resistivity lows in these contexts could be caused by shearing, alteration, serpentinization, or accumulations of sulfide or oxide minerals.**

**Although modeling results are hypothetical, reasonable agreement between the geophysical and geochemical data sets is achieved by modeling the Red Mountain complex as a sill-like body which is thickest at the south end and includes a magnetite-rich layer at depth, possibly along the floor. The favored interpretation is that multiple injections of magma intruded northward from the southern end of Red Mountain, allowing later intrusions to dome and fracture earlier dunite and peridotite and to remobilize PGEs locally. Deep targets at Red Mountain are indicated along the possible floor of the complex near the southern Border Zone, within the Border Zone itself and in low-resistivity rocks beneath the massif.**

**Because it is only partially unroofed and has received less work, less is known about the platinum potential at Susie Mountain. However, zoned soil anomalies are associated with pipe-like structures and high Fe:Mg ratios, suggesting a potential for near-surface PGE concentrations.**

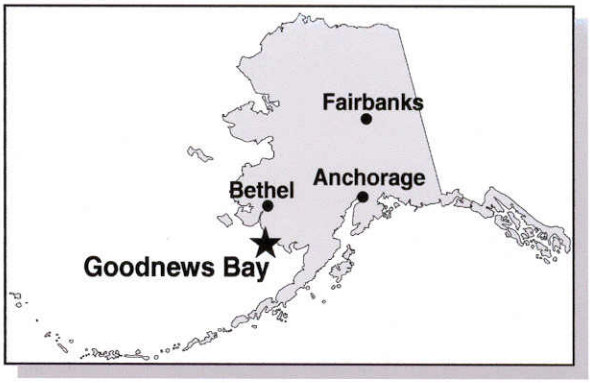


**Figure 1. State of Alaska showing project location.**

## INTRODUCTION

Two Alaska-type zoned ultramafic intrusives located south of Goodnews Bay in southwest Alaska (Figure 1) have long been recognized as the source of more than 20.2 tonnes (650,000 ounces) of placer platinum mined from the gravels of local streams (Mertie, 1976; Southworth and Foley, 1986). Lode exploration activities during the past few years have included extensive geophysical efforts, have added to the geochemical coverage, and have refined knowledge about the distribution of rock types. These efforts have also integrated geophysical and geochemical information from earlier work (Hinderman, 1989, 1995a, 1995b; Hinderman and others 1994; Van der Poel, 1994; Van der Poel and Hinderman, 1997). The recent efforts have yielded convergent indicators from resistivity, magnetic, gravity and geochemical data showing strong evidence that deeper portions of the complexes are prospective for platinum mineralization. In addition, it is apparent that some promising near-surface geochemical targets have yet to be fully tested.

The lode mineral property includes approximately 207 square kilometers (80 square miles), controlled by Corral Creek Corporation of Denver, Colorado under lease from Calista Corporation, a regional Native corporation organized under the Alaska Native Claims Settlement Act. The area is near tidewater that is ice-free all year.

## GEOLOGY

As is typical of Alaska-type complexes, the ultramafic bodies at Red and Susie Mountains generally show a rough, concentric lithologic zoning outward from dunite cores, through peridotite and clinopyroxene-dominant rocks, to hornblende-dominant rocks, including hornblende pegmatites of metasomatic origin (Figure 2). Varying degrees and types of serpentinization are pervasive in olivine-rich lithologies. Units composed dominantly of clinopyroxene and hornblende are herein referred to as the *border zone* lithologies since they are mostly located along contacts with the metasedimentary and metavolcanic host rocks of the Gemuk Group. The Goodnews complexes differ from many other Alaska-type complexes in that true pyroxene-bearing gabbros have not been recognized around the margins.

The surface of the Red Mountain complex (Figure 2) is dominated by a core of dunite, surrounded by relatively thin, discontinuous bands of border zone rocks. The surface of the Susie Mountain complex however, is primarily underlain by clinopyroxen- and hornblende-rich units, surrounding relatively limited dunite exposures. The distribution of lithologies, coupled with inferences drawn from geophysical and geochemical data, indicate the Susie complex is only partially unroofed compared to the Red Mountain complex.

The authors' favored interpretation for the origins of the complexes infers that partial differentiation by gravity settling in the intrusions produced a clinopyroxene-rich phase, a process recognized in Alaska-type complexes by many authors, including Irvine (1974) and Taylor (1979). Doming of the layered sequence by later, underlying intrusions, along with temperature-gradient diffusion and possible flow differentiation, contributed to the concentric zoning. Multiple intrusions of ultramafic magma also caused minor contact metamorphism of the country rock and the intrusions were themselves contaminated on their margins, creating hydrous phases such as the hornblende-dominant rocks. The fact that dikes of all units cut other units and that portions of the complexes exhibit reversed magnetic polarity (see below) strongly support the multi-phase interpretation. Recent mapping indicates that some of the smaller dunite occurrences on Susie Mountain may be late-stage, pipe-like features of metasomatic origin which were intruded into crudely layered zones of clinopyroxenite and peridotite.

Geologic mapping, CSAMT, and magnetic data indicate that, near the surface, the southeast margins of both complexes as well as the northeast margin of the Susie complex dip steeply (Van der Poel and Hinderman 1997). Gravity data for the northwest margin of Red Mountain are most easily modeled as the thinning edge of a sill-like body.

The Red and Susie Mountain complexes are compa-

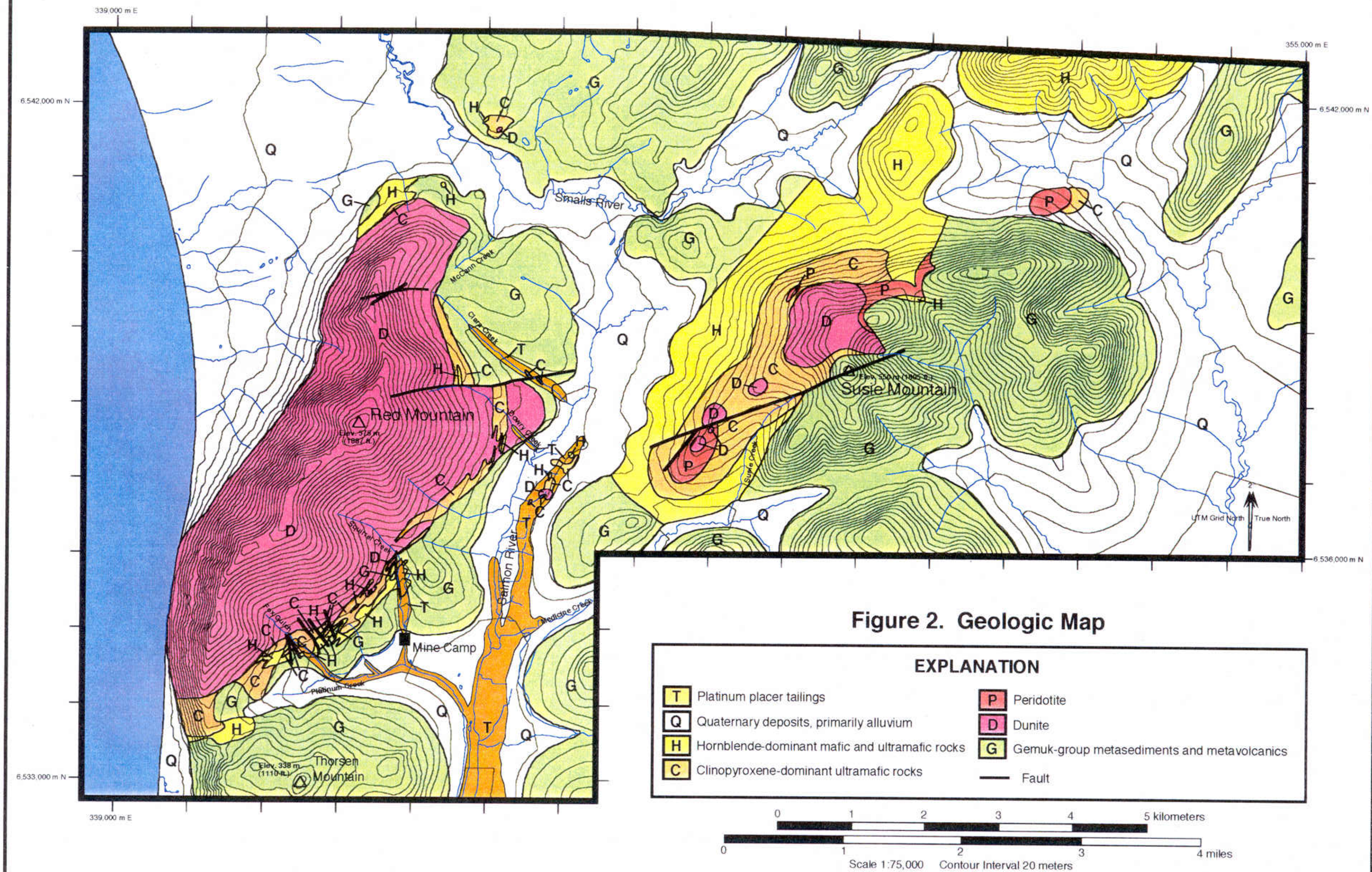


Figure 2. Geologic Map

rable, both lithologically and chemically, to the Uralian Nizhnii Tagil type of platinum-bearing forsterite dunites described by Razin (1974). Strong similarities also exist with complexes on the Kamchatka Peninsula which shed gravels currently being exploited by Koryak Geology and Mining. Scientists from that company have described recrystallized dunite as a favorable indicator of platinum concentrations (E. G. Siderov, oral communication).

## MINERALIZATION

To date, all production of PGEs (platinum group elements) from the Goodnews complexes has come from placers. Placer minerals are dominantly Pt-Fe alloy intergrown with chromite and as subordinate Os-Ir alloy, though the ratios of these elements vary in different parts of the complexes (Mertie, 1976). The most significant lode occurrences are of the same mineralogy, typically hosted in chromite schlieren in dunite. Minor sulfide occurrences have been recognized but are not statistically correlated with increased platinum values (Hinderman, 1989; Southworth and Foley, 1986; Kieser, 1995).

Zeintek and others (1992) have shown that the chondrite-normalized proportions of PGEs in the Goodnews complexes are typical of Alaska-type complexes, with Pt and Ir elevated relative to Pd. Pt:Pd ratios range from10:1 to 100:1 or greater. This pattern differs from sulfide-dominant systems such as Stillwater and Bushveld that are typically enriched in both Pt and Pd.

Since 1988, there have been 2,130 meters (7,000 feet) of trenching, and 1,860 meters (6,100 feet) of drilling on the property. The best intercept was 2.6 ppm in 1 meter (3 feet) of dunite adjacent to a serpentinite zone at Fox Gulch. The trenching and drilling have primarily been limited to the lower slopes of Red Mountain and drilling has only penetrated to depths of 60 meters (200 feet) or less. There has never been any trenching or drilling on Susie Mountain and several good lode targets in both complexes remain untested.

## GEOCHEMISTRY

Soil and rock geochemical sampling show the Red and Susie Mountain complexes are enriched in platinum overall, with the average of over 5,700 soil samples close to 32 ppb Pt. A prominent two-lobed anomaly in the central part of Red Mountain (Figure 3) has soils with 60 to 3,300 ppb Pt, and covers an area of approximately 1,700 meters (5,600 feet) by 700 meters (2,300 feet). Another series of high platinum soil values defines a trend that extends a distance of about 700 meters (2,300 feet) across the west ridge of Susie Mountain (Figure 4). At its widest point, it is about 100 meters (325 feet) in width. The anomalous samples in this area average 130 ppb Pt, with a maximum of 345 ppb. The Susie Mountain anomaly occurs on the margin of a small, possibly metasomatic, dunite body and may be related to it, and/or a fault zone which forms a prominent regional linear.

Only the lower part of the Red Mountain anomaly has been tested by drilling and trenching, which did not detect significant mineralization in-situ. This may indicate that remobilized platinum occurred in portions of structures that have now been eroded and/or that a residual concentration occurrs in soil.

Significant differences occur in the geochemical associations of soil platinum between Red and Susie Mountains. At Red Mountain, higher values of Pt are generally associated with higher values of Ni, Fe, Co, Mg and with lower Cr:Mg and Cr:Fe ratios. In contrast, high Pt values from Susie are associated with lower contents of Fe, Mg and Ni and with higher Fe:Mg, Cr:Fe and Cr:Mg ratios (Van der Poel, 1994). Some of these geochemical relationships resemble those noted in deeper versus shallower parts of other types of zoned intrusives hosting mineable PGEs at depth (Chai and Naldrett, 1992; Naldrett and Cabri, 1976), suggesting that potential for massive or semi-massive mineralization may increase with depth at Goodnews and that Red Mountain represents a deeper portion of the system.

At Susie Mountain, concentrations of platinum in soil show evidence of chemical zoning in the distribution of chromium, iron and magnesium around the

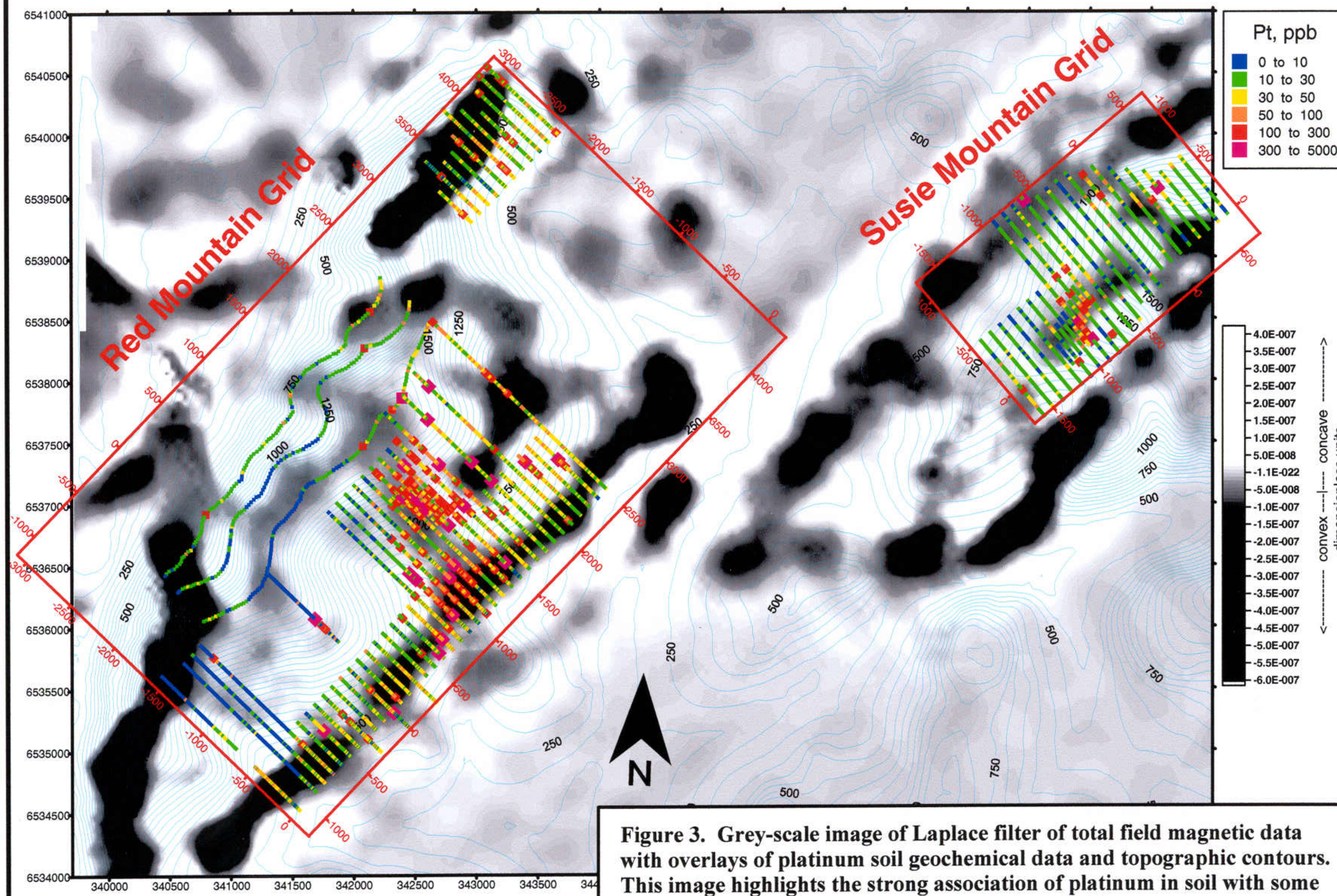


**Figure 3. Grey-scale image of Laplace filter of total field magnetic data with overlays of platinum soil geochemical data and topographic contours. This image highlights the strong association of platinum in soil with some magnetic ridges, here represented by darker shading.**

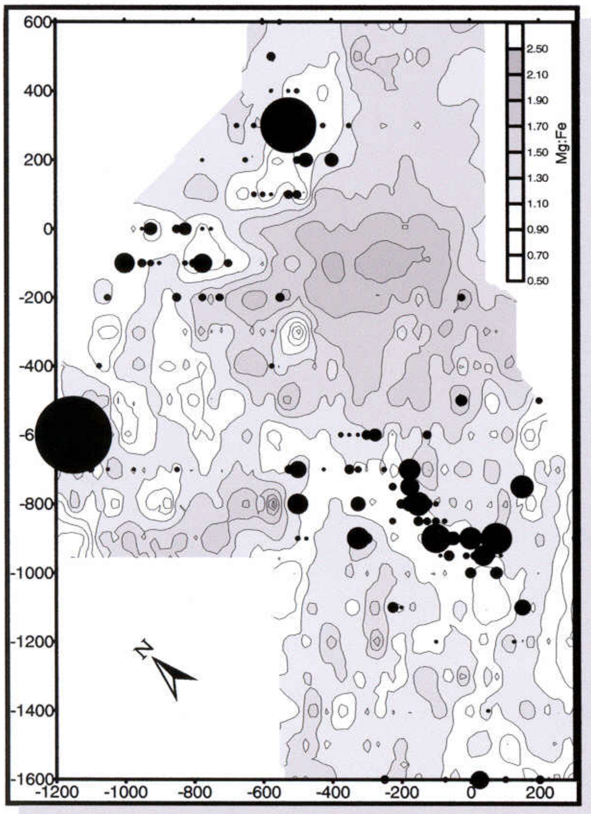


**Figure 4. Contours of Fe:Mg ratio with platinum in soil as dots, Susie Mountain soil grid. Lighter shading represents higher Fe:Mg, largest dot represents 2,000 ppb Pt**

platinum anomaly. Soil platinum correlates well with elevated ratios of Fe:Mg, forming a roughly concentric pattern around high-magnesium dunite near the peak (Figure 4). It is noteworthy that the mineralized portions of the high-Mg trend have elevated magnetic response and occur near both shallow and deep zones of reduced resistivity.

## GEOPHYSICS

The total magnetic field is a resultant of both induced and remanent components. The induced component arises when the earth's magnetic field interacts with magnetic minerals in rock, while the remanent component is the spontaneous direction and intensity of magnetization dating from the rock's formation, as modified during it's history. Factors effecting the induced component at Goodnews include the content of both primary and secondary magnetite and possibly a minor contribution from ilmenite, high-iron chromite and other magnetic spinels. Secondary magnetite has developed both along contacts and in the interior of the complex as a result of various stages of metasomatism and serpentinization.

At Goodnews, laboratory analysis of oriented surface samples shows that remanent magnetism is the dominant contributor to the total field. While much of the remanent component on Red Mountain is oriented only 20-30 degrees east of the current magnetic field, portions of the northwest and southwest margins exhibit reversed polarities. In these areas, the remanent component opposes the induced component and depresses total field values below regional norms (Figure 5)(Van der Poel and Hinderman, 1997). The presence of the reversed-polarity portions of the complex indicate that it consists of at least two intrusions which were separated by a fairly long period of time, supporting an intrusive structural analog with oceanic spreading ridges, at which younger rocks displace older rocks outward. The low inclination of the remanent magnetism also suggests that the complex rocks may have originally cooled at low latitudes before being transported to their current location (Sheriff, 1997).

Total field airborne magnetic data show the complexes have distinctive signatures which are more extensive than indicated by the distribution of outcrop and rubble and may underlie as much as 47 square kilometers (18 square miles), about twice the surface exposure. Filtering of the total field magnetic data reveals that ridges in the field occur in more-or-less cellular patterns, some of which show radial and concentric tendencies suggestive of fracture above diapiric intrusions (Figure 5). Though a degree of topographic influence is suspected in this representation, close inspection reveals many of the most significant convexities in the filter crosscut topographic features.

Smooth model inversions of CSAMT data for the Red and Susie Mountain areas (Figures 6, 7) show the surficial units are underlain by rocks of moderate-to-low resistivity at depths as great as 1,000 meters (3,280 feet)(Zonge Engineering, 1996).

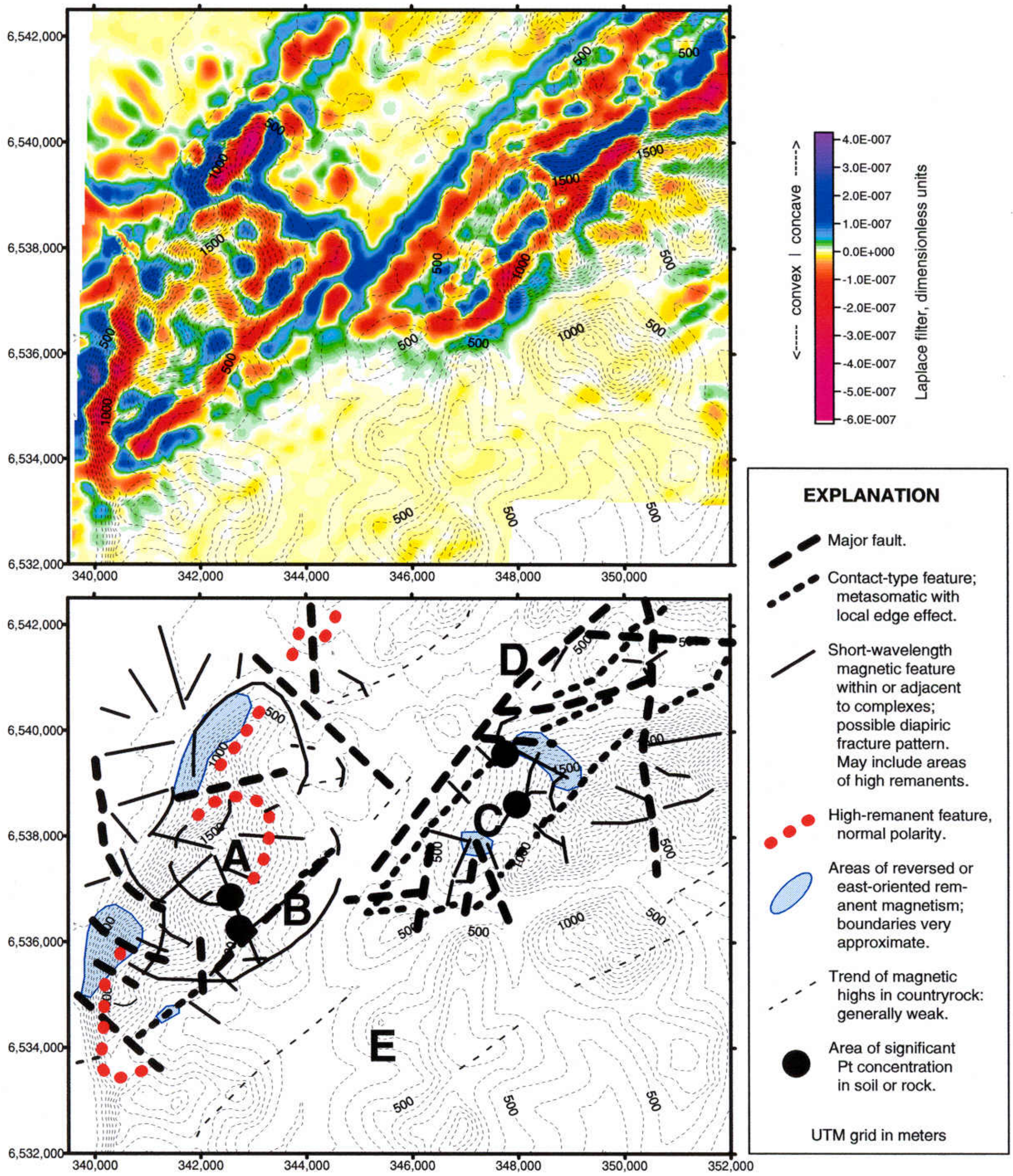


**Figure 5. Laplace filter of total field aeromagnetic data, with interpretation. This filter has applied a Laplacian operator to the data and shows ridges or convexities in the field as warm colors, troughs or depressions in the field as cool colors. A; apparent center of radial and concentric pattern suggesting underlying diapir. B; border zone fault and contact metamorphic environment. C; magnetic ridges in cell-like pattern, possibly representing fracture with diapiric attributes. D; bounding fault on north side of Susie Mountain complex. E; non-complex rocks showing regional northeast trends of magnetic features.**

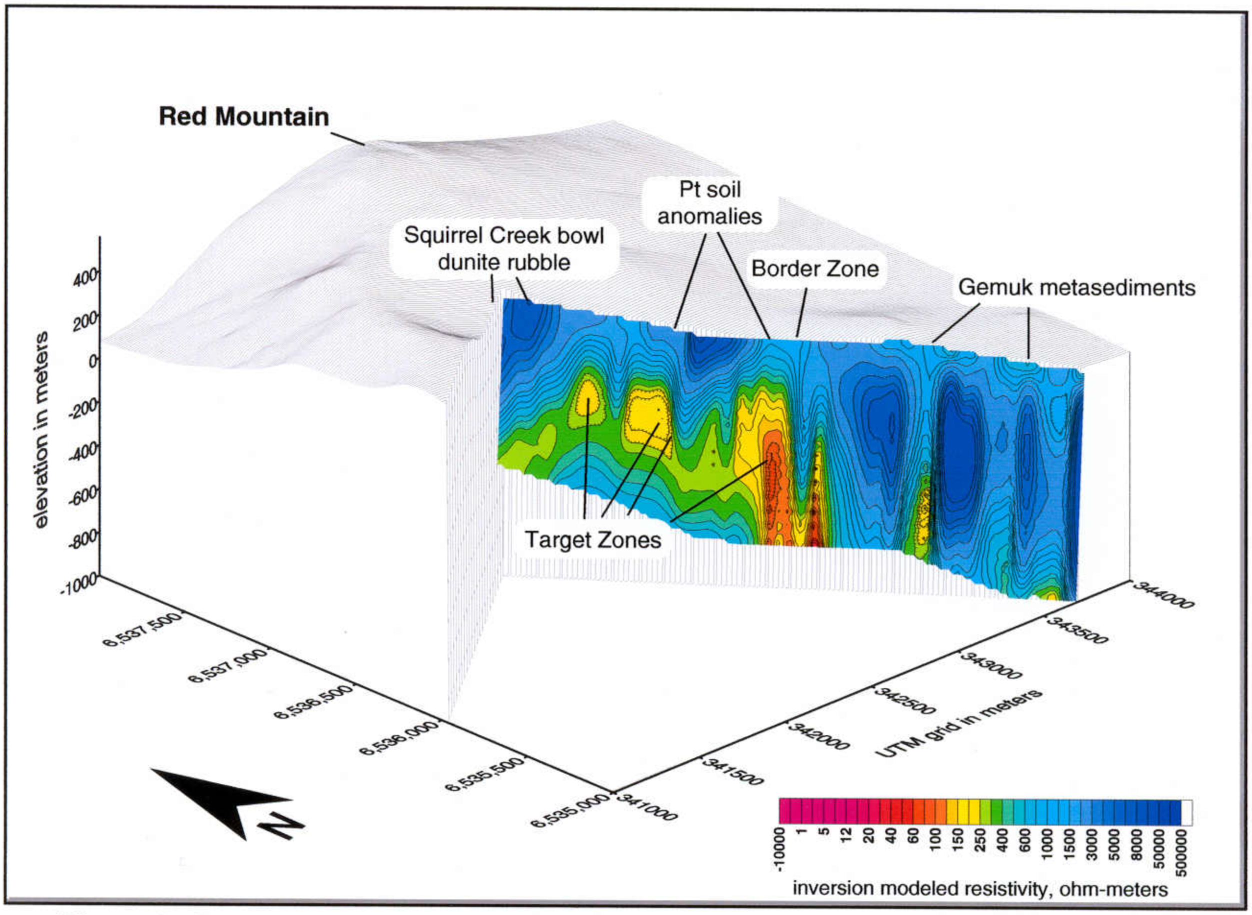


**Figure 6. Orthographic block diagram of the Red Mountain area with CSAMT profile 8N. Warmer colors represent lower resistivities**

The resistivity models define an undulating, gently dipping layer or discontinuity within the complex, bounded by a steeply dipping low beneath the border zone at Red Mountain. A similar, though less exten sive zone of moderate resistivity is recognized within the Susie complex. Zones of low-to-moderate resistivity could indicate serpentinization, alteration, shearing around chromitites, accumulations of pyroxene or sulfide minerals, or some combination of these features. Zones of elevated magnetic and gravity fields combined with low resistivity could indicate concentrations of magnetite, possibly accompanied by chromite, or pyrrhotite.

Complementing these data, magnetic modeling suggests that both complexes could have floors 1 - 2 kilometers (3,280 - 6,580 feet) deep if susceptibilities are relatively uniform with depth (Pearson, 1996). These depths are considerably greater than the resistivity lows and if correct, would indicate the zones of moderate and low resistivity occur within, rather than at the base of the complexes. The magnetic models also suggest the Susie Complex may have an extension to the southeast at depth, possibly indicating a feeder or a sheared segment along a deep thrust.

Gravity data collected in the Red Mountain area show a north-south gradient with elevated values along the southern border zone (Figure 8), (Burns and Carlson, 1997). The Bouguer gravity in Figure 8 has been calculated using a density of 2.30 grams/cc to overcome terrain effects believed to be caused by limitations in the resolution of existing topographic data and by the low density of nearby surface materials. In spite of the ambiguities, the data allow reasonable confidence that the complex has a relatively shallow floor on its north end which

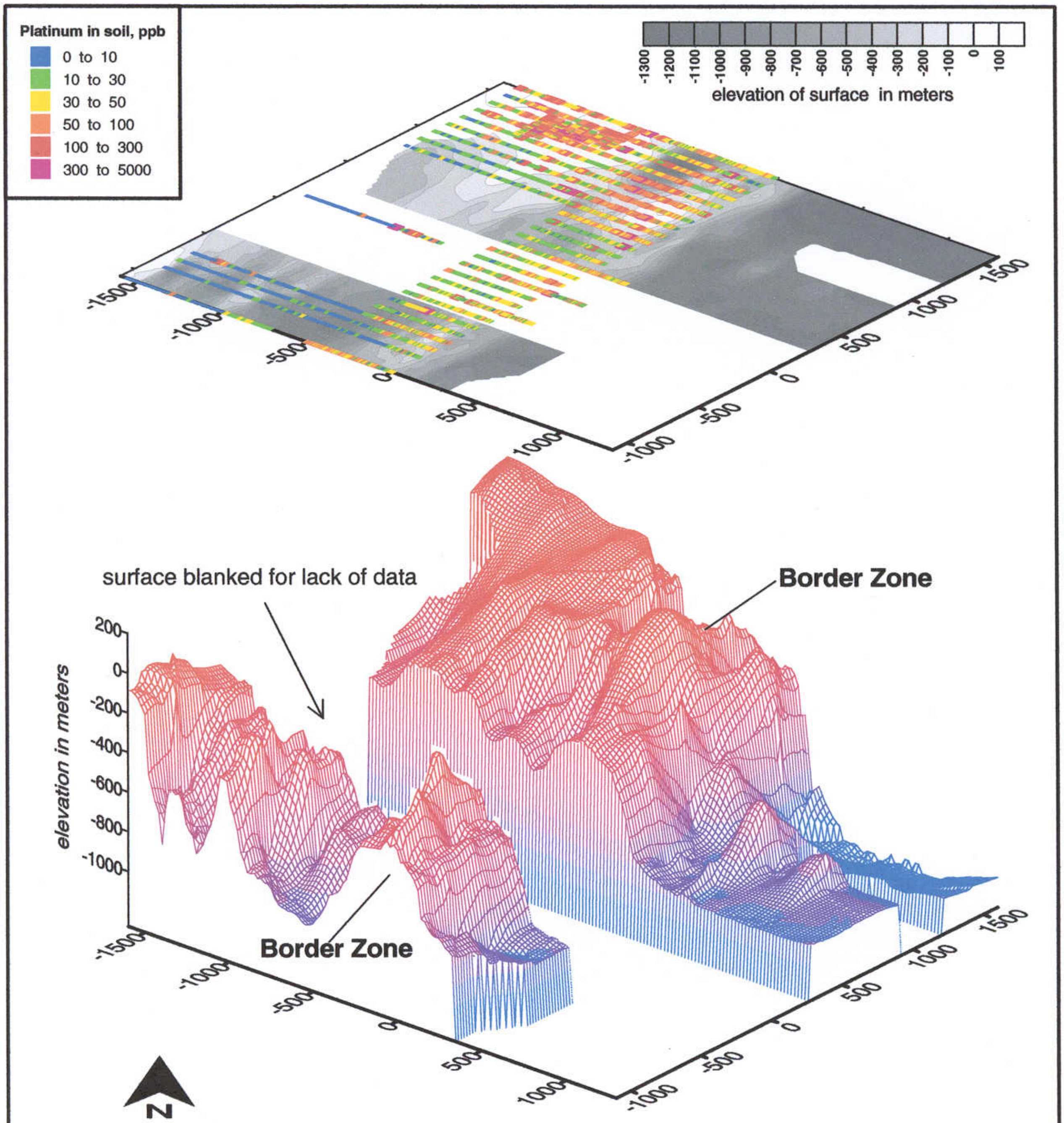


**Figure 7. Bottom; orthogonal 3-D view of the 250-ohm-meter surface beneath part of the Red Mountain grid. This surface represents the top of low- and moderate-resistivity rocks defined by smooth model inversion of CSAMT data. Top; Stacked orthogonal view of the plan map of the 250-ohm-meter surface as grey-scale contours, overlaid with soil geochemical data. Zones of elevated Pt in soil are most intense in proximity to upward projections in the resistivity surface, the tops of which lie approximately 300 to 1,000 meters beneath the earth's surface. This relationship indicates a strong vertical component to processes which effect both the geochemical and resistivity features. Comparison with gravity data suggests the surface northwest of the Border Zone could represent the floor of the complex.**

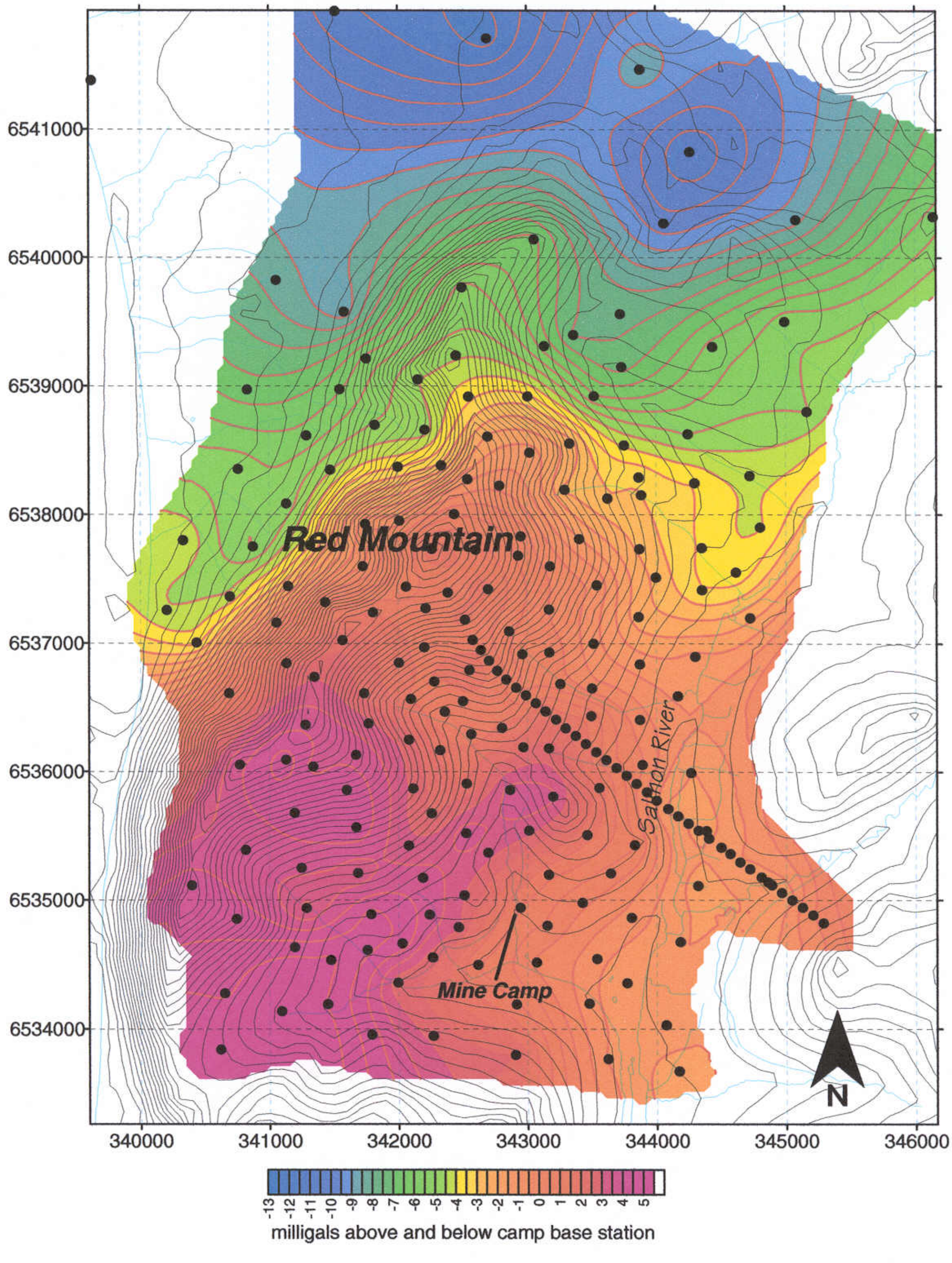


**Figure 8. Bouguer gravity of the Red Mountain area, processed at an assumed density of 2.30 g/cc and overlaid on topography, shown as black lines. Dots show survey stations; warmer colors indicate greater mass in the subsurface. The northeast-trending gravity high along the southern border zone, north and west of the mine camp, suggests a deep feeder structure or a concentration of dense minerals underlie the area.**

deepens to the south and southeast. While underlying thrusts can not be ruled out, modeling can accommodate a deep feeder beneath the southern end of Red Mountain and the southern border zone. In contrast to magnetic modeling using uniform susceptibilities, gravity models can accommodate a floor with a similar depth and configuration to the low-resistivity interface modeled by CSAMT.

Modeled depths to the floor of the complex, as indicated by the gravity, magnetic and CSAMT data, can be reconciled by employing densities that are lower than expected, or susceptibilities and intensities of remanent magnetism which are higher than expected. Geologic conditions which might account for this could include strong alteration beneath the floor, uncharacteristically light serpentinite at depth and/or a layered, magnetite- rich zone near the floor of a sill-like complex.

## EXPLORATION MODELS

Alaska-type zoned ultramafic complexes have high intrinsic platinum contents compared to other types of ultramafic rocks, and they have shed important reserves of placer platinum worldwide. To date, they have yielded no significant platinum lode production in the western hemisphere, but zoned complexes in the Russian Urals and the Far East have been mined for localized, pod-like ore bodies in dunite. Alaska-type complexes have not received much attention in the west and the nature of mineralization in them is not well understood. However, their lithologic and chemical make up, as well as the physical process of PGE concentration, have many similarities to other productive ultramafic complexes and mineralization models based on these other types of deposits may apply.

One genetic hypothesis that accommodates the data postulates that platinum-enriched intrusions ascended from a fissure-like feeder beneath the south end of Red Mountain and moved obliquely northward with a tapering, sill-like geometry. Mid-stage intrusions partially differentiated beneath cooled dunite and were domed and disrupted by late-stage magma, allowing serpentinization and/or recrystallization and platinum remobilization along fractures (Figure 9). Based on this framework and similarities with productive deposits in other areas, PGE concentrations at Red and/or Susie Mountain could occur as the following:

1) Accumulations of PGE-bearing sulfide or oxide minerals, concentrated by gravity, in depressions along the floor of the intrusives, possibly in or near feeder structures. This model will be hardest to test, but may have the greatest size potential. The tendency for concentrations of soil platinum to occur over ridges in the magnetic field, and for both these features to be associated with upward projections of low-to-moderate resistivity rock within the complexes, may suggest the surface showings are leakage from more significant mineralization as much as a thousand meters (3,280 feet) beneath the surface. The combination of elevated gravity response, magnetic highs and resistivity lows along the border zone provides a signature that could be associated with concentrations of magnetite or pyrrhotite at depth. Ore deposits in mafic/ultramafic rocks in which gravity concentration and settling have enriched grades in the lower portions of complexes are numerous and include Norilsk, the Kluane Belt of northwest Canada, Jinchuan, China, Voiseys' Bay and the lower chromitites at Stillwater.

2) PGE concentrations in magnetite pyroxenite in the deeper portions of the Border Zone, or in sulfides formed from contamination by countryrock. In some cases, such as at Fifield in New South Wales, Australia, platinum is concentrated in magnetite clinopyroxenite of the border zones of Alaska-type complexes (Suppel and Barron, 1986). Much of the 1987 and 1988 work at Goodnews focused on the border zone, with generally negative results, but zones of economic mineralization could have been missed. More significantly, the relatively new resistivity and magnetic data indicate conditions conducive to Fifield-type mineralization are much better developed at depth near Fox Gulch than they are at the surface.

3) PGEs in breccias related to late-stage, crosscutting intrusions. The tendency for PGE mineralization to occur at contacts of intrusive complexes and at brecciated, discordant boundaries within them is

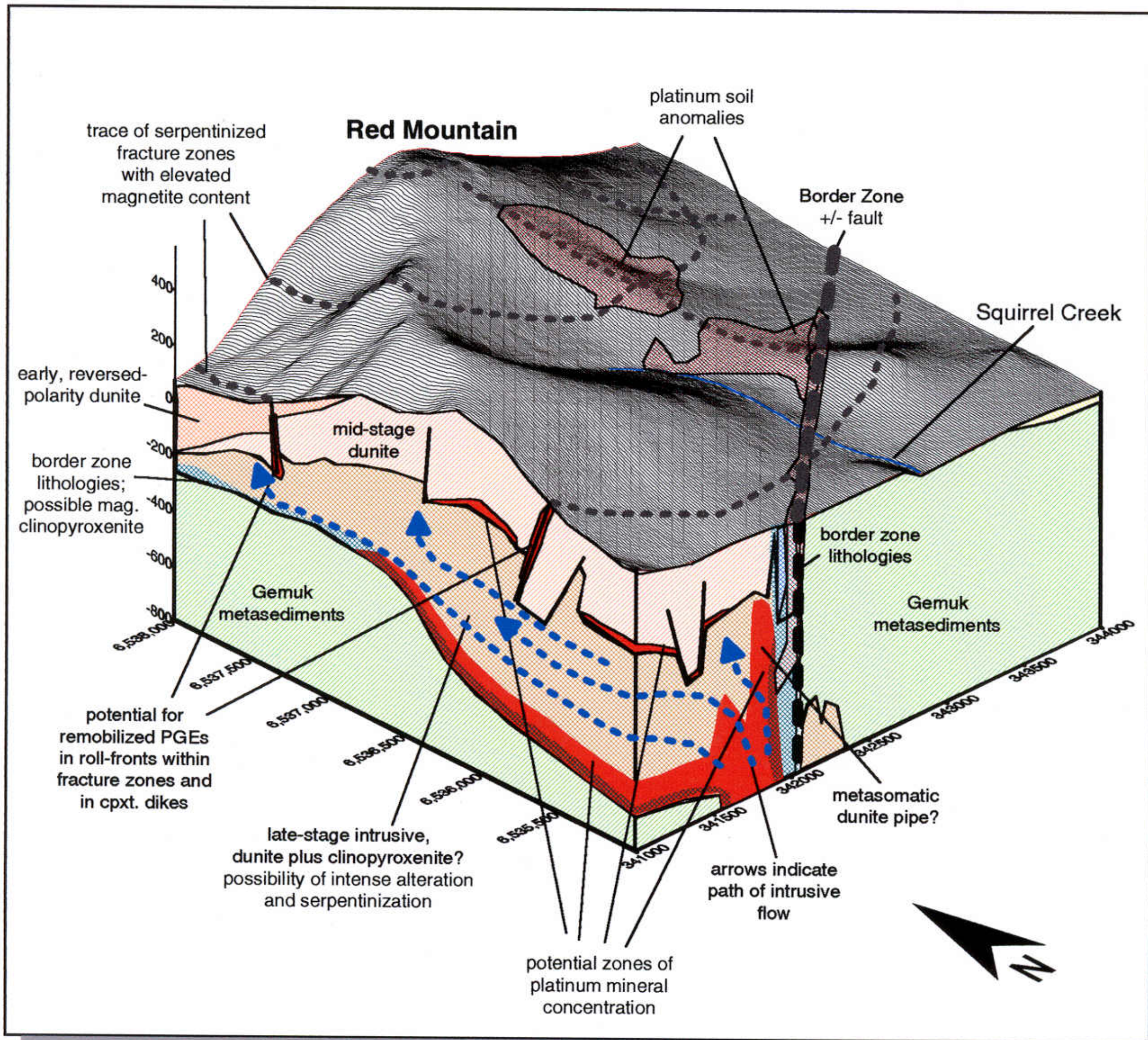


**Figure 9. Hypothetical block diagram of the Red Mountain area showing features indicated by surface mapping, geophysics and geochemistry.**

demonstrated at the Lac des Isles complex and the potentially related River Valley deposits in Ontario. The tendency for sulfides to be encountered near the contacts at Goodnews supports the hypothesis of contact-related mineralization, as does the lithologically-related pattern of concentration at Susie Mountain. Brecciation may be a more common feature than has been recognized to date at Goodnews and forthcoming field work will reevaluate this potential.

4) Platinum concentrations as Pt-Fe alloy in metasomatic dunite pipes. Pipe-like ore bodies of PGE-enriched dunite replacing bronzitite occur at the Bushveld Complex (Stumpfl and Rucklidge, 1982, Naldrett, 1981). The observation that the Bushveld pipes contain higher proportions of Pt-Fe alloy than the reefs suggest similarities to the Susie Mountain anomaly, where platinum occurs with high Fe-Mg ratios in soil and dunite pipes intrude peridotite nearby. Crosscutting bodies of metasomatic dunite are also recognized in the Alaska-type complex at Duke Island (Irvine, 1974). The importance of hydrous-phase processes and serpentinization in the

redistribution of platinum-group elements from silicate to sulfide and platinum-iron alloy have been discussed by Stumpfl and Tarkian (1976), by Naldrett (1981) and by various Russian investigators.

5) <u>PGE concentrations in reef-type cumulate segregations in underlying intrusions</u>.
Though reef-type occurrences similar to Stillwater and Bushveld are less likely to occur than some other types of mineralization, and would certainly be of limited extent, the recognition of magnetite and chromitite cumulate layering in other Alaska-type complexes indicates they could be present at depth at Goodnews. If the undulating zone of low resistivity beneath Red Mountain is not the floor of the complex, it may represent a differentiated phase of an underlying intrusion, perhaps clinopyroxenite. Since some of the numerous crosscutting clinopyroxenite dikes are enriched in platinum, this zone could represent a source with potential for a reef-type mineralization.

6) <u>Platiniferous chromite in pods or disseminated in dunite of the core of the complexes</u>. The chromite pods in the Nishniy-Tagil region in Russia are very high in grade but tend to be small. There are, however, on-going experiments with grinding and gravity processing of chromite-bearing dunite at Kondeur, an Alaska-type complex in the Russian Far East, at which a pilot-scale plant produced 75 kg (2,400 oz) of platinum in 1998 (T. K. Bundtzen, oral communication). The exposed surface dunite of the Goodnews complex is not notably rich in chromite, but there has been no systematic investigation, and chromite concentrations may not be exposed or may exist at depth.

7) <u>PGE concentrations in zones of serpentinization formed by late-stage hydrous-phase activity along fractures or at contacts between intrusive phases</u>. There is evidence that hydrous alteration which causes serpentinization can also concentrate platinum (Hulbert and others, 1988), and the best drill intercept on Red Mountain was in dunite on the margin of a large serpentinite zone. Fault and fracture zones are generally known to concentrate mineralization, and the arcuate geochemical anomaly on Susie Mountain could represent platinum concentrated by serpentinization.

## ADDITIONAL INVESTIGATIONS

The geochemical anomalies on both Red and Susie Mountains may be evidence of near surface mineralization and should be investigated by additional sampling, trenching, and/or drilling. Priority targets for deeper drilling include both high and low portions of the moderate-resistivity feature beneath Red Mountain, the resistivity low accompanying the magnetic and gravity high beneath the Border Zone, and a potential feeder structure beneath the south end of Red Mountain. Many of these targets occur at depths as great as 1,000 meters (3,280 feet). Holes at least 1,600 meters (5,250 feet) in depth will be necessary to accommodate angle drilling.

A continuation of the geophysical effort will include refinement of models and a modest program to acquire additional data. This program should further define known targets, possibly identify new ones and improve the knowledge base for directing deep drilling as it progresses. Continued rock and soil sampling, along with surface prospecting, may discover subtle targets and will also continue to define structure and properties of mineralization.

A phased, two- or three-year program to accomplish these objectives will require expenditure of approximately $2.5 million, approximately $500,000 of which could be allocated to additional surface exploration during the first year. Corral Creek Corporation is seeking the participation of a JV partner to share costs and opportunities.

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The authors have no direct interest in the property but may receive compensation for referral of partners to Corral Creek Corporation, at who's request this report has been prepared.

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