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# GIS Based Marine Platinum Exploration, Goodnews Bay Region, Southwest Alaska

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*Goodnews Bay, southwest Alaska, is known for platinum (Pt) reserve that extends offshore in the Bering Sea. To assess the nearshore placer potential we first collated marine Pt concentrations available since 1960 in a geographic information system (GIS) database. Subsequently, in 2005, we collected 23 pipe dredge sediment samples and 26 vibracores from unexplored sites and analyzed them for Pt. This sampling was supplemented by magnetic (Sea Spy) and seismic (side scan, geoacoustic and datasonic bubble pulser) surveys. Integrating results of geospatial analysis of Pt concentrations with geophysical analysis using GIS techniques led to delineate four locations encouraging for further Pt exploration. Of these, two locations fall close to paleochannels and drowned ultramafic source, while the other two coincide with high energy environments in the Goodnews Bay and close to the Carter Bay.*

**Keywords** Beringia, geodatabase, glaciation, image analysis, magnetic, seismic, ultramafic

Platinum (Pt) metal has several industrial applications, particularly in the making of jewelery and use in electronics and strategic military components. Pt resources in the United States (US) are very limited. One of the largest resources is the alluvial placer

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deposit in the Red Mountain region and Goodnews Bay, in southwest Alaska (Figure 1), from which at least 22 tons of Pt have been recovered (Barker, 1986). The Red Mountain dunite is considered the primary source of Pt in this region (Harrington, 1919; Hoare and Coonrad, 1961; Mertie, 1969). Due to depletion of the shallow economic reserves, this area has not been mined since the 1980's.

The United States Geological Survey (USGS) estimated the marine Pt placer potential for the Goodnews Bay region at 155 metric tons (Page et al., 1973; Barker, 1986). Several investigations for government agencies, individuals, and corporations have tried to assess the marine Pt resource in offshore of Goodnews Bay. However, these assessments have not incisively estimated the resource potential. The first objective of this study is to integrate all marine Pt placer related data for the Goodnews

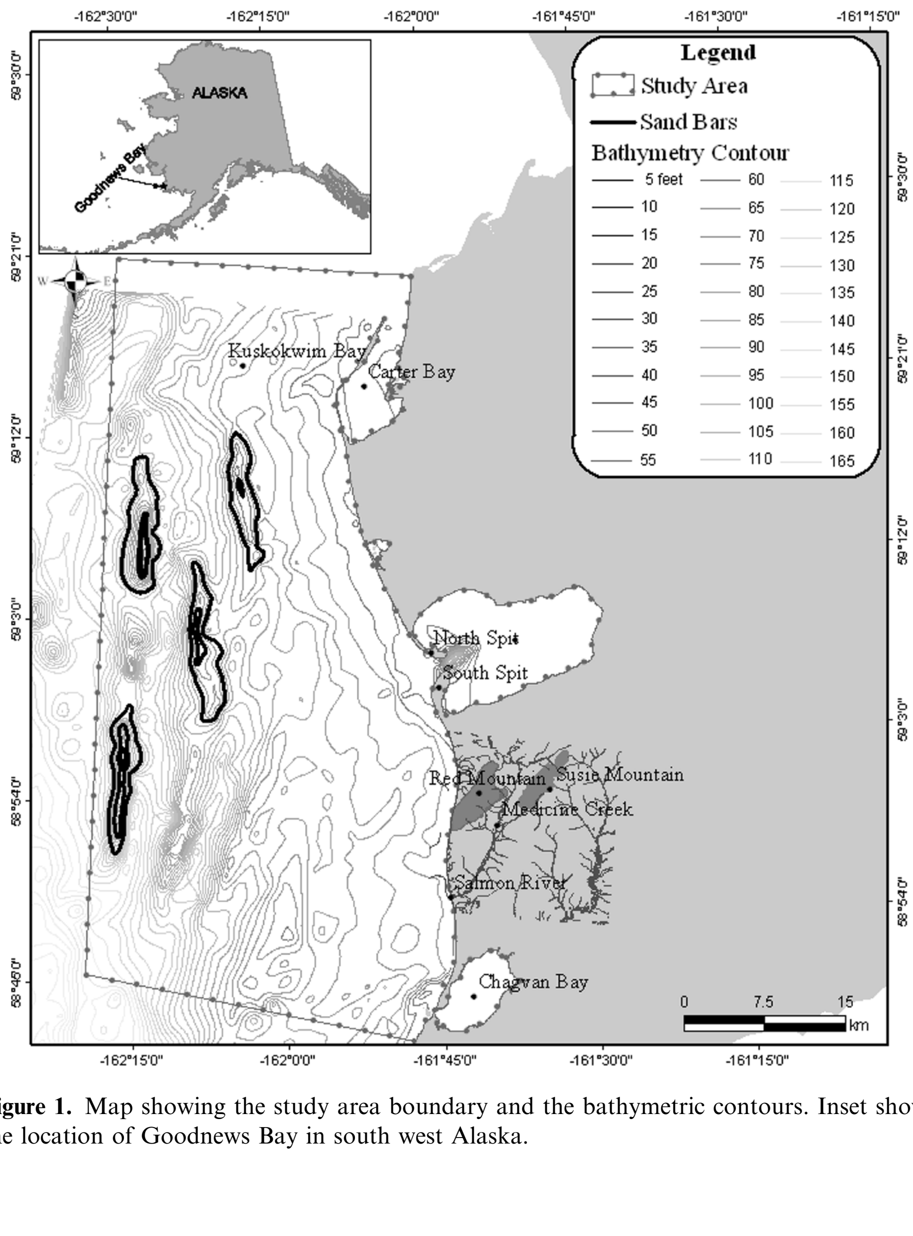


**Figure 1.** Map showing the study area boundary and the bathymetric contours. Inset shows the location of Goodnews Bay in south west Alaska.

Bay coastal area with the intent to identify data gaps. The second objective is to augment the Pt assessments, especially from areas where there is a paucity of data, and to integrate all available information in a GIS database. Additional aim is to analyze the entire dataset using GIS techniques to identify potential sites for further exploitation and/or in-depth exploration for marine Pt placer deposits in the study area.

The selection of the study area (Figure 1) for Pt placer resource estimation is based on three major reasons. One, that the area is adjacent to Red Mountain, which is long known to be the source of Pt in the adjacent coastal region. Two, the recent paleoenvironmental history of the area could have been favorable for placer evolution. A third reason is the occasional report of Pt occurrence in the Goodnews Bay offshore. During the Pleistocene the eustatic sea level in this region fluctuated, with the glacial sea level about 120 m below the present level $\sim$21 ky B.P (Hopkins, 1967; Manley, 2002). During this time, there existed a land bridge, the Beringia, connecting Alaska and Russia. The post-glacial transgression that occurred $\sim$5-3 ky B.P closely defined the present coastline. The isobath map of the study area reveals presence of several sand bars, aligned parallel or sub-parallel to the present coastline (Figure 1). Presumably, the sand bars are submerged paleobeaches, an environment generally characterized by intensified wave sorting and concentration of heavy minerals (with possible entrained Pt grains). An analogous scenario is the offshore (and onshore) paleo-marine gold placers of the Nome region (Nelson et al., 1972).

The Pt that has been mined from the hinterland of the Goodnews Bay region is confined mostly to Salmon River and its tributaries draining the Red Mountain (Figure 1). The Red Mountain is a large sill like dunite mass that is repeatedly exposed by one or more north-south (N-S) trending folds or faults, and at places covered by a thin layer of country rock and surface sediments (Barker, 1986). Therefore, there is a probability of the presence of buried folded or faulted ultramafics in the offshore region. The paleochannels draining these ultramafics, and the ancient analog of the Salmon River now submerged, are potential locations for Pt exploration (Mertie, 1940).

In this study, we have collated all Pt-placer related information, available since 1960, into a geodatabase, have identified data gaps, and followed by collection of new geophysical and Pt data on sediments from the offshore region. Finally, we have analyzed all this data, using GIS techniques, to delineate offshore areas of potential Pt resource accumulation.

## Geodatabase

Geodatabase, the database behind a GIS, offers a practical solution to integrate data with reference to its geographic location. Using inbuilt GIS tools, these data can then be effectively managed, analyzed and visualized to understand complex processes. The power of the GIS lies in its potential to query the database, generate thematic maps, and to serve as a decision support system. The Goodnews Bay region geodatabase included existing Pt concentrations; geophysical data; new data acquired by us during the "Platinum Cruise 2005"; available bathymetry data; satellite image data; published glacial extent information; geologic maps; and limited interpretations from earlier researcher. The most important of these datasets are briefly described in the following sections. The Goodnews Bay region geodatabase is hosted at http://mms-goodnewsbay.gina.alaska.edu/.

### *Platinum Concentrations*

Prior to our investigation, four agencies together assessed the Pt values for 428 locations for the study area (Figure 2). Of these 428 data points, 316 were collected by the Inlet Oil Corporation, Alaska (Conwell, 1976); 31 were contributed by the USGS; 54 were reported by the United States Bureau of Mines (USBM); and the remaining 27 came from Western Gold Exploration and Mining Limited Partnership (WestGold) (Howkins, 1988; Barker and Lamal, 1989; Oommen, 2006).

However, the inventory of the Pt data from these agencies revealed that most of the data were within the 4.8 km state offshore jurisdiction, and that there was a paucity of data from farther offshore region (Figure 2).

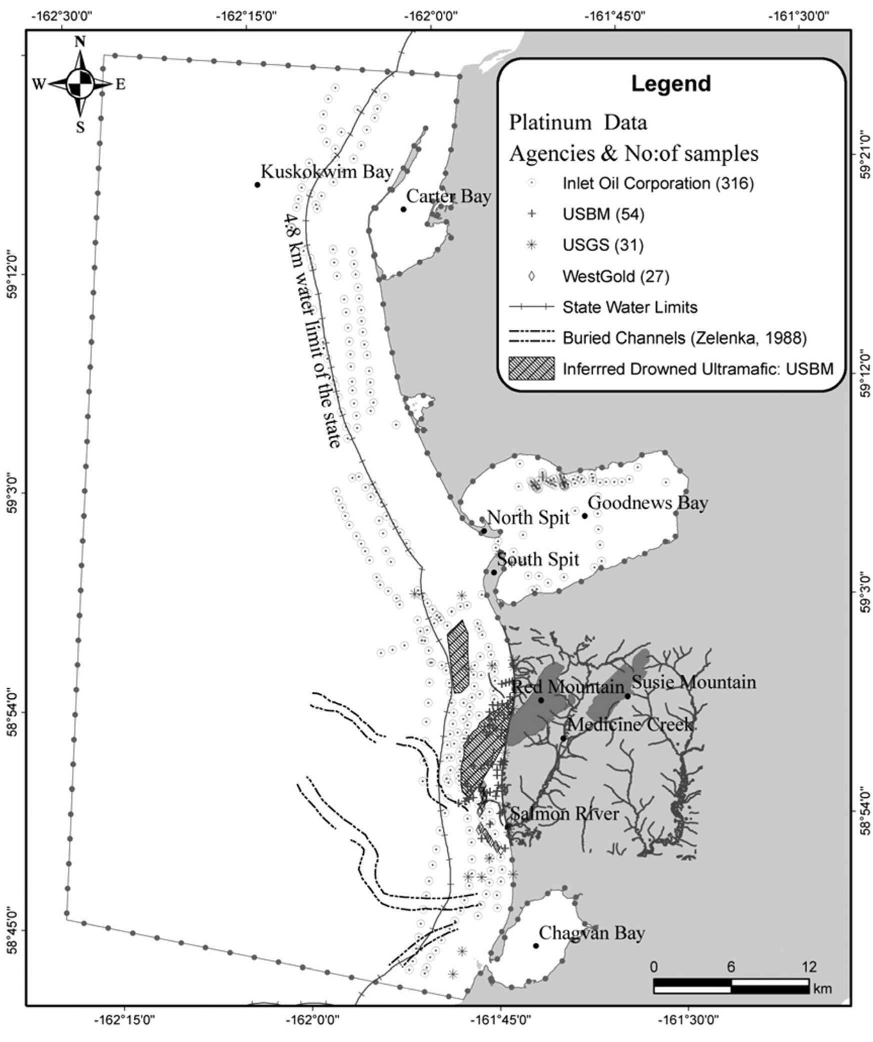


**Figure 2.** Location of available platinum and geophysical data from the study area obtained by several different agencies in the past. There are 77 samples within the Goodnews Bay 400 outside the bay.

### *Geophysical Data*

The USBM in 1988 conducted a geophysical survey in the study area and indicated the possible presence of drowned ultramafic rocks offshore (Figure 2). The major findings of their study are:

1. The magnetic anomalies immediately south of Red Mountain (offshore, Figure 2) reflect an extension of the Goodnews Bay ultramafic complex (Barker et al., 1988; Barker and Lamal, 1989).
2. The magnetic anomalies northwest of Red Mountain (Figure 2) in the offshore are possibly displaced by a fault or a convoluted fold similar to the one onshore between the Red and Susie mountains (Southworth and Foley, 1986; Barker et al., 1988).
3. The structure of the ultramafic complex northwest of Red Mountain appears to extend farther west beyond the survey lines of 1988. However, these are interpreted from widely spaced transects and needed further investigations (Barker et al., 1988; Barker and Lamal, 1989).

Zelenka (1988) interpreted the offshore seismic data collected by the USGS in 1969 and identified three possible buried paleochannels (Figure 2). However, he stated that "these channel locations are approximate and high resolution data is required to verify and define their locations."

## Platinum Cruise 2005 and Sample Processing for Pt Contents

The "Platinum Cruise 2005" was conducted in summer 2005 to fill in data gaps for the comprehensive analysis of the Pt resource potential in the study area. The specific activities of the cruise included collection of 23 pipe dredge sediments and 26 vibracore samples from unexplored sites off Goodnews Bay (Figure 3). This sampling was supplemented by magnetic (Sea Spy) and seismic (side scan, Geoacoustic and Datasonic bubble pulser) surveys. The details of the cruise, instrumentation used and on sediment collection are addressed in Oommen (2006). The sediment samples for Pt estimation were processed following the method outlined by the USBM (Barker et al., 1988). Briefly, each of the short (1–3 m long) vibracore samples were extruded into a trough to make a gross sample. So was each of the pipe dredge samples. From the individual gross sample $\sim$750 g of sand and silt fraction was separated by wet sieving using a nest of screens followed by repeated washing out fraction after clay. From known weights of each of the dried sand and silt fraction the heavy mineral fraction was separated, using methylene iodide (specific gravity: 3.2), and weighed. About 20–30 g aliquot of the heavy mineral concentrate was taken for Pt analysis by fire assay (ALS Chemex, 2005). Assuming negligible Pt present in the gravel and clay size, the Pt concentrations in the sand and silt fractions were combined and prorated to the gross sediment.

## Analysis

We analyzed all available data for the Goodnews Bay region in three phases to delineate the potential locations for marine Pt resource. The first phase was to include the Pt values in the geodatabase to model their spatial distribution. In the second phase,

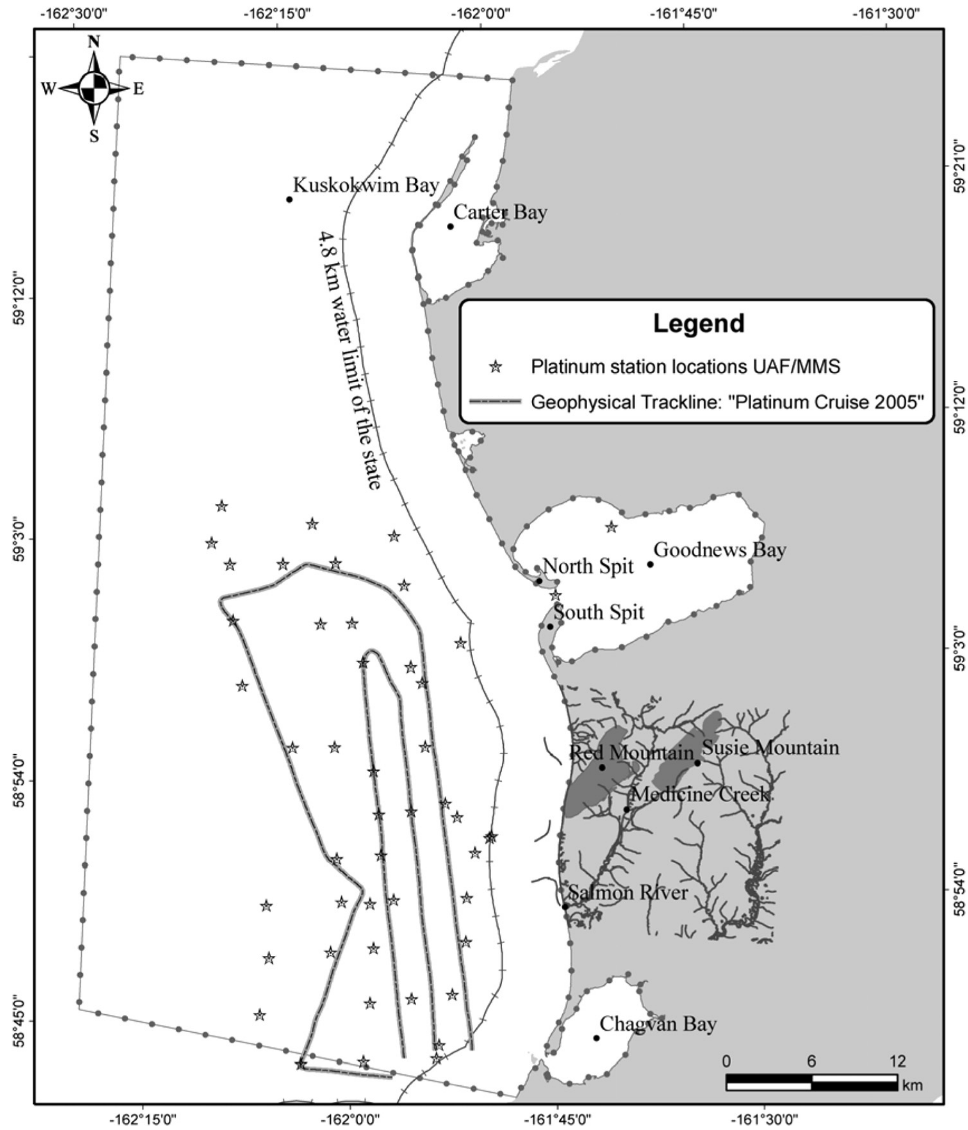


**Figure 3.** Sediment sample location and geophysical trackline of the data collected by UAF/MMS as part of the "Platinum Cruise 2005".

the geophysical data collected during "Platinum Cruise 2005" were analyzed along with existing data to identify the location of ultramafic rock and paleochannels in the marine environment. In the third phase, the dispersal pattern of the sediment plume was examined using satellite imagery and interpreted in context of the prevailing coastal current. Subsequently, we compared the spatial distribution of Pt to the patterns of coastal current and suspended sediment distribution, locations of drowned ultramafic, paleochannels, and the sand bars, to assess the influence of these factors on the Pt occurrence.

### *Phase I: "Precious Metal Analysis"*

Over the last five decades, five different agencies have sampled and analyzed 477 data points of Pt values from the Goodnews Bay region. This number includes the 49 data points included by the University of Alaska Fairbanks in 2005. Out of these data points, 77 samples were collected within Goodnews Bay and 400 samples were from outside the bay (Figure 2).

In order to determine the spatial trends in the Pt concentrations, we used the global trend analysis tool available in ArcGIS 9.1 (Johnston, 2003). The Pt data within the Goodnews Bay did not show any spatial trend. However, the concentrations outside the bay depicted significant trends in the north-south direction (Pt values increasing to the north), and east-west direction (Pt values highest in the center and decreasing to east and west) (Oommen, 2006).

Histogram analysis to understand the statistical distribution of the Pt data resulted in histograms showing a skewed distribution of 1.52 and 1.47 for outside and inside the bay, respectively. This high positive skewness implies that a greater proportion of the Pt data are less than or equal to the mean (Isaaks and Srivastava, 1989), and that higher values of Pt, both outside and inside the bay, are possibly concentrated in small areas. The statistics of the Pt data are provided in Table 1.

It is to be noted that Inlet Oil Corporation was the sole agency that sampled and analyzed the data points for Pt inside of the bay. For the data points outside the bay, the Inlet Oil Corporation and the USGS performed Pt analysis on the entire grab sample, whereas the USBM, UAF and WestGold Inlet Corp. used the heavy mineral crop of the gross sample to assess the Pt content. The latter values were then converted to represent the Pt content in the entire sample.

We note that the mean Pt concentrations on gross grab samples are considerably higher than those obtained on heavy mineral separates (Table 2). This suggests that there is a possible loss of Pt grains in the heavy mineral separation process and/or there is relatively less Pt-bearing particles in the heavies. To address the possible Pt loss we looked at an analogous situation relating to gold. Figure 4 shows the graph for heavy mineral separation for gold recovery. Assuming that the graph is applicable to Pt distribution (as the specific gravity of Pt is close to that of gold, the particles bearing these metals should have similar hydraulic equivalence), we conclude that a considerable loss occurs in the recovery of Pt in our samples when the particle size is $<100\ \mu m$. This conclusion is consistent with the observation of Moore (1971), who reported that 74% of Pt to be in the silt-clay fraction ($<100\ \mu m$) and $\sim 26\%$ in size $>100\ \mu m$ in the offshore region of Goodnews Bay. We modeled the spatial distribution of Pt outside the bay, once considering the actual reported values

**Table 1.** Statistics of the Pt data within and outside the Goodnews Bay

| | Pt data within the Bay $mg/m^3$ | Pt data outside the Bay $mg/m^3$ |
|---|---|---|
| Minimum | 0 | 0 |
| Maximum | 1600 | 1080 |
| Mean | 341.1 | 161.85 |
| Standard deviation | 330.61 | 200.96 |
| Skewness | 1.47 | 1.52 |

**Table 2.** Minimum, maximum and mean value of Pt obtained by different agencies in the study area

| Agencies | Minimum pt (mg/m$^3$) | Maximum pt (mg/m$^3$) | Mean pt (mg/m$^3$) | Sample fraction analyzed |
|---|---|---|---|---|
| Inlet Oil corp | 20 | 1600 | 270 | Whole sample |
| USGS | 10 | 700 | 120 | Whole sample |
| USBM | 0 | 180 | 7 | Heavy mineral concentrate |
| WestGold | 0 | 40 | 2 | Heavy mineral concentrate |
| UAF/MMS | 0 | 70 | 5 | Heavy mineral concentrate |

of Pt concentrations, and a second time with adjusted Pt values to account for the loss factor (Oommen, 2006).

In our study the spatial distribution of Pt concentrations was analyzed by applying a radial basis function (RBF) model, using ArcGIS 9.1 (Johnston, 2003). Prior to the model development, we split the available data into two random subsets. The larger subset comprising 80% of the data was used as a 'training data' for developing the model, while the smaller 20% subset served as the testing data to verify the reliability of the results based on the first subset. Using the larger 80% subset for training ensures that there are sufficient data points for the model development. To assess and validate the developed model, we subsequently used standard performance measures such as root mean square error (RMSE), mean absolute error (MAE), correlation coefficient (r) and coefficient of efficiency (E) (Nash and Sutcliffe, 1970). Table 3 shows the performance measures obtained for the validation of the RBF model using the testing data.

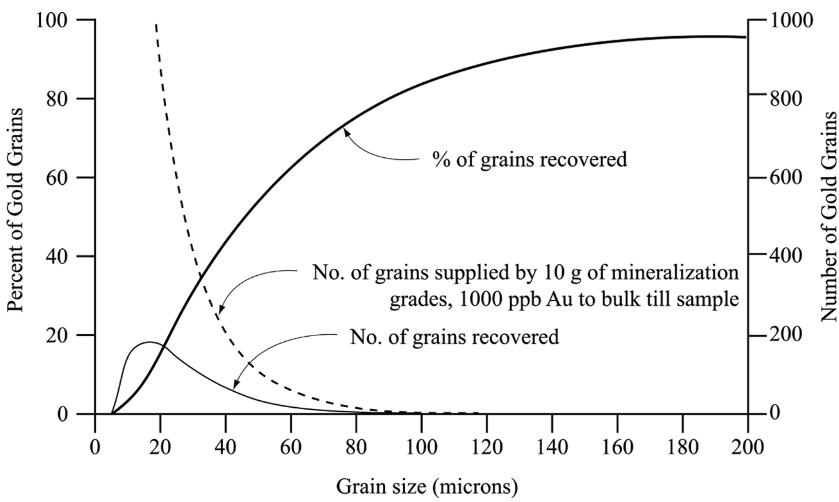


**Figure 4.** Plot of gold recovery vs. grain size during heavy mineral separation. Adapted from ODM laboratories, Ontario, Canada (agency who carried out heavy mineral separation for sediment samples collected from "Platinum Cruise 05").

**Table 3.** Performance measures for the spatial distribution of Pt using RBF within and outside the goodnews bay

| RBF | Pt data within Bay | Pt data outside the Bay | Pt data outside the Bay with loss factor |
|---|---|---|---|
| RMSE | 255.09 | 159.03 | 159.85 |
| MAE | 200.64 | 108.12 | 109.24 |
| r | 0.57 | 0.55 | 0.54 |
| E (%) | 28.31 | 27.11 | 25.95 |

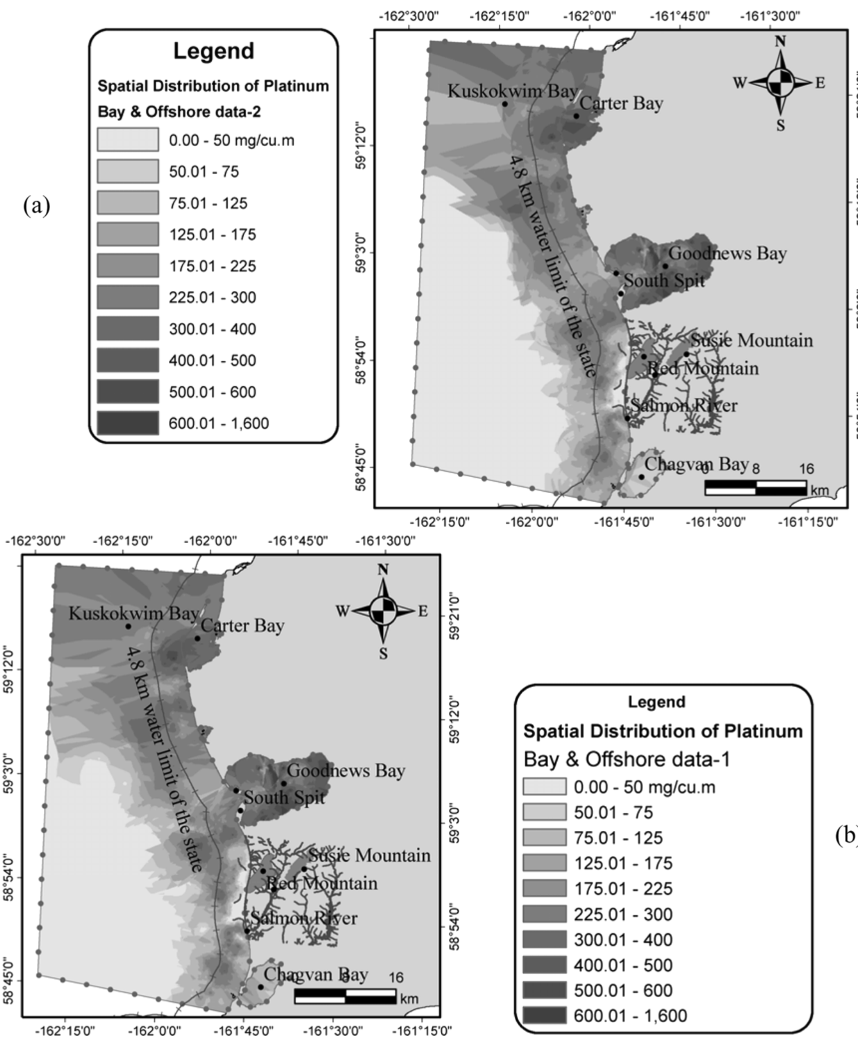


**Figure 5.** Spatial distribution of platinum in the study area developed using RBF (a) using the loss factor (b) without the loss factor.

The models developed for the prediction of Pt inside and outside the Goodnews Bay were combined to develop the prediction map for the entire study area. The Pt distribution map for the study area developed using the data from inside the bay and outside bay with and without loss factor is given in Figures 5(a) and 5(b). A comparison of Figures 5(a) and 5(b) reveals that there was no significant change in the spatial distribution pattern of Pt by incorporating the loss factor.

## Phase II: Geophysical Analysis

### *Magnetic Data Analysis*

Using a nearest neighbor interpolator, we interpolated and contoured the magnetic data obtained from the "Platinum Cruise 05". A magnetic value exceeding $\pm 500$ gamma from the mean (53581 gamma) was symbolized as a magnetic anomaly, as shown in Figure 6. This was the same procedure that USBM had adopted for marine magnetic data analysis in this region in 1988 (Barker et al., 1988; Barker et al., 1989). The contour map shows several magnetic anomalies on the near shore transects. These anomalous values, which ranged 2000–3000 gammas (Figure 6), are usually associated with ultramafic rocks (Dyment et al., 2005).

We studied and compared the results of the magnetic data obtained from "Platinum Cruise 05" in light of the geology, structure of the ultramafics and the records of the past magnetic surveys in this region. Overlaying the marine magnetic data recorded by the USBM on the magnetic anomalies mapped by us (Figure 6) reveals that the ultramafics extend farther west of the location mapped by the USBM in 1988.

### *Seismic Data Analysis*

In order to map the subsurface geologic features and verify the extension of submerged paleochannels in the offshore of Goodnews Bay, we visually analyzed the seismic reflection data from "Platinum Cruise 05". This analysis identified two paleochannels; one west of Red Mountain, and the other towards the south of the study area (Figure 7). We also compared these channels to the ones identified by USGS (Zelenka, 1988) (Figure 7). Of the three paleochannels identified by the USGS, the channel in the north closely coincides with the findings of the "Platinum Cruise 05." The paleochannel identified south of the study area seems to be a continuation of the paleochannel identified by the USGS (Figure 7), and is possibly an extension of the Salmon River analog, which flowed into the Chagvan Bay area in last glacial interval (Mertie, 1940).

Overlaying the paleochannel locations on the inferred magnetic anomalies (Figure 8) reveals that the paleochannel west of Red Mountain passed in between the magnetic anomalies (inferred drowned ultramafic: "Platinum Cruise 05", Figure 6). At the present time the Salmon River, which runs in the proximity of the ultramafic rocks (Red and Susie Mountains), has entrained most of the alluvial placer Pt that has been locally mined. Figure 8 shows that a condition analogous to that observed onshore (Salmon River) exists offshore, suggesting that the paleochannel identified near the buried ultramafics is a location for rich resource potential for placer Pt.

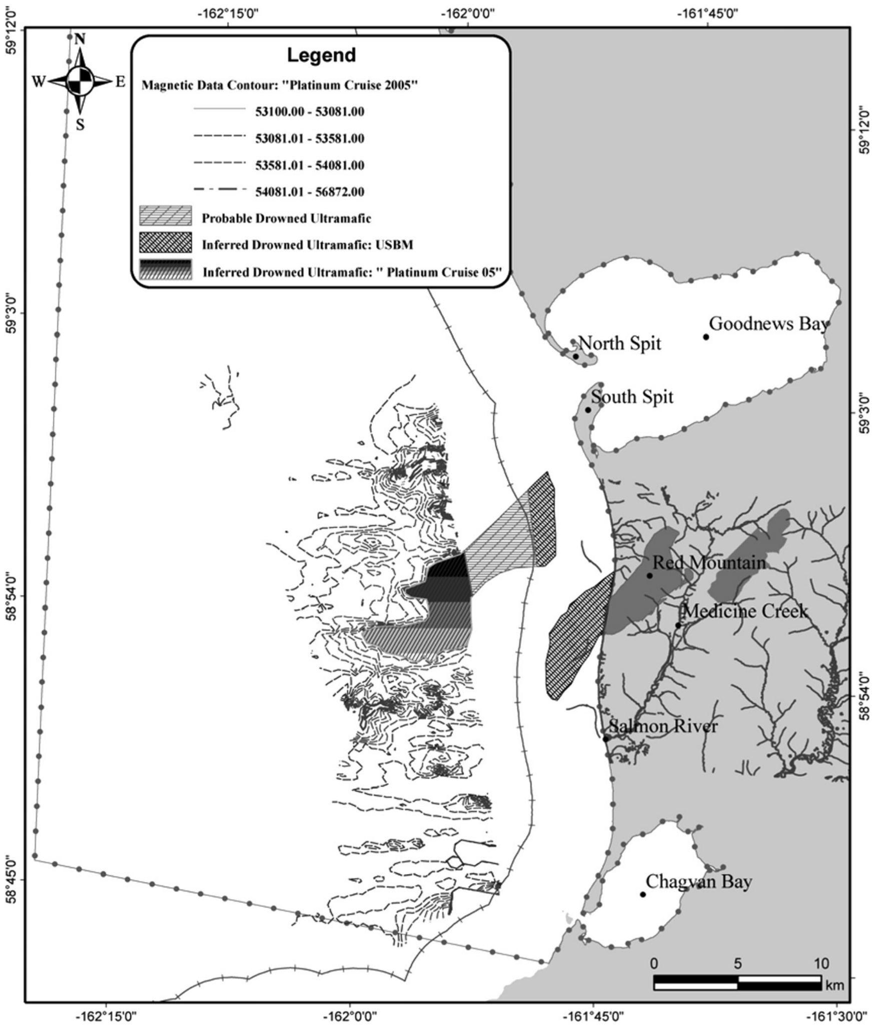


**Figure 6.** A comparison of the magnetic interpretation from USBM (Barker et al., 1988) to the magnetic data collected from "Platinum Cruise 05".

## Phase III: Assessment of Suspended Sediment Distribution

We used a natural color composite image from Landsat 7 Enhanced Thematic Mapper (ETM), acquired on 27 September 2000, to understand the suspended sediment distribution pattern (Edwards and Mumby, 1999), the transportation processes of the suspensates, and to deduce from the distribution low and high energy depositional environments in context of placer Pt deposits. In order to obtain a better visualization of the sediment plume, a contrast stretching image enhancement was applied. The intent of contrast stretching was to broaden the narrow range of reflectance values typically present in an input image over a wider range of grey values (Lillesand et al., 2004). Figure 9 shows the enhanced image overlaid with the direction of longshore sediment transport as determined by the USGS (Hunter et al., 1979). The enhanced image shows that there is a relatively larger sediment load

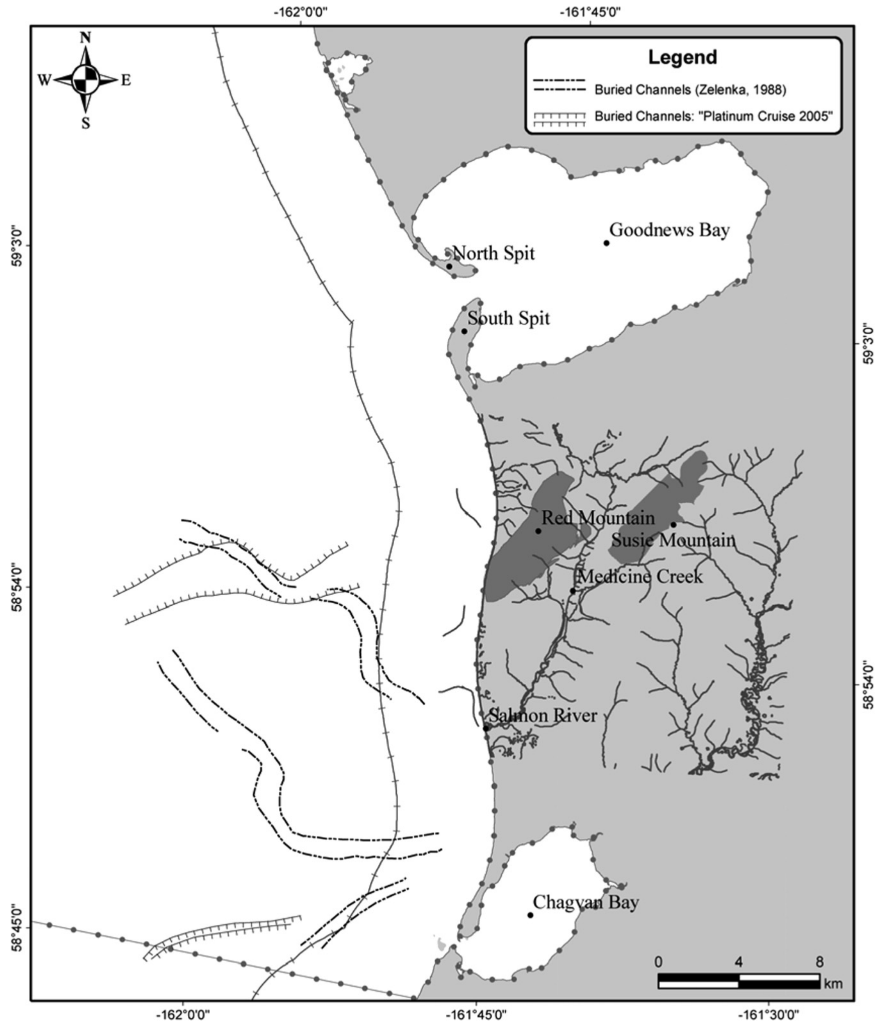


**Figure 7.** A comparison of the paleochannels identified by USGS (Zelenka, 1988) with the channels identified from the seismic data obtained from "Platinum Cruise 05".

inside Goodnews Bay and the area close to Carter Bay in the north. The large amount of suspended sediment load reflects either or both of two possibilities. One, that the area is subjected locally to greater suspension of particles from reworking of bottom sediments by site-specific intense nearshore currents. The alternative explanation is that the area has larger input of terrigenous suspended sediment plume which has not settled out to the bottom because of high turbulence. In either case the area reflects presence of relatively high energy depositional environment.

## Integrated Analysis

Finally, we used GIS techniques to integrate maps showing the inferred spatial distribution of Pt, drowned ultramafic, paleochannels, coastal current direction,

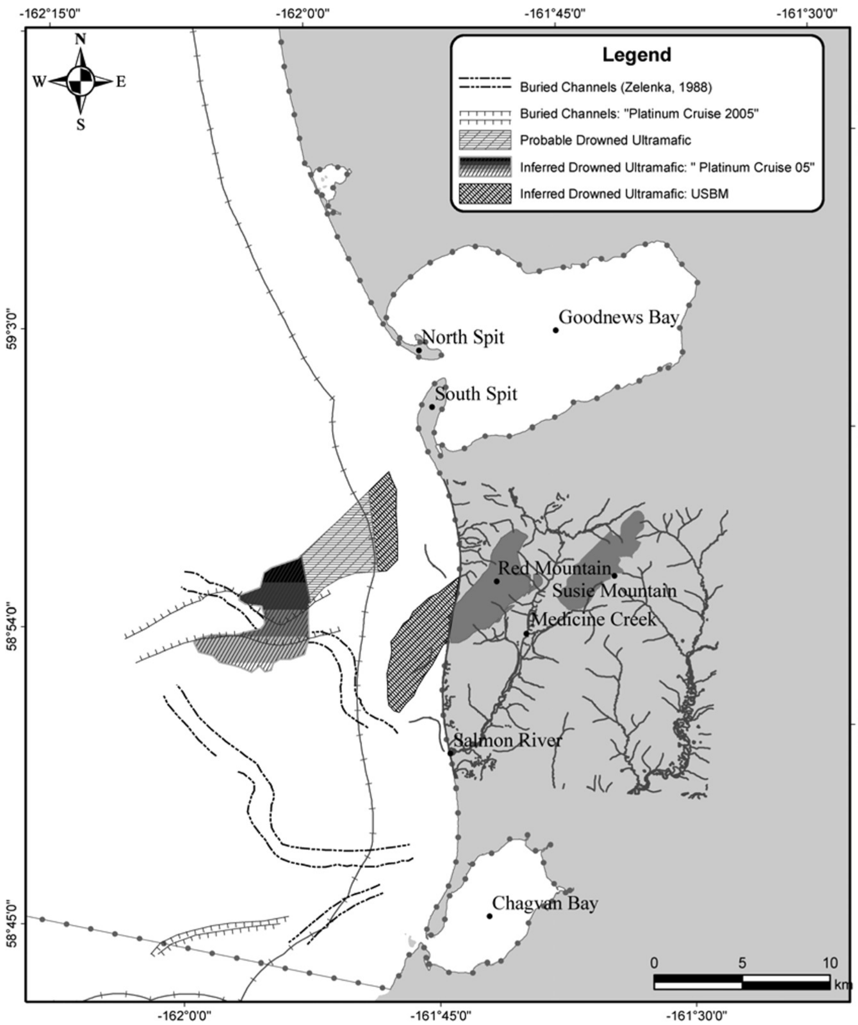


**Figure 8.** A comparison of the magnetic and seismic data interpretation from the study area.

sediment distribution pattern and the sand bars in a geographically consistent manner (Figure 10), in an attempt to find correlations and to better constrain the factors influencing the Pt distribution pattern. However, Figure 10 shows no particular correlation between drowned ultramafics, paleochannels and high Pt concentrations. The probable reason for this is that the seismic data analysis had identified the bottom of these channels to be about 20–40 m deep and that they are covered with modern sediments. It is likely that in these sites, at depths greater than what we sampled in the "Platinum Cruise 2005", higher Pt concentrations occur.

The comparison of the spatial distribution pattern of Pt and the sediments (Figures 9 and 10) in the study area suggests that both Pt and the suspended sediments are high inside the Goodnews Bay and regions close to Carter Bay in

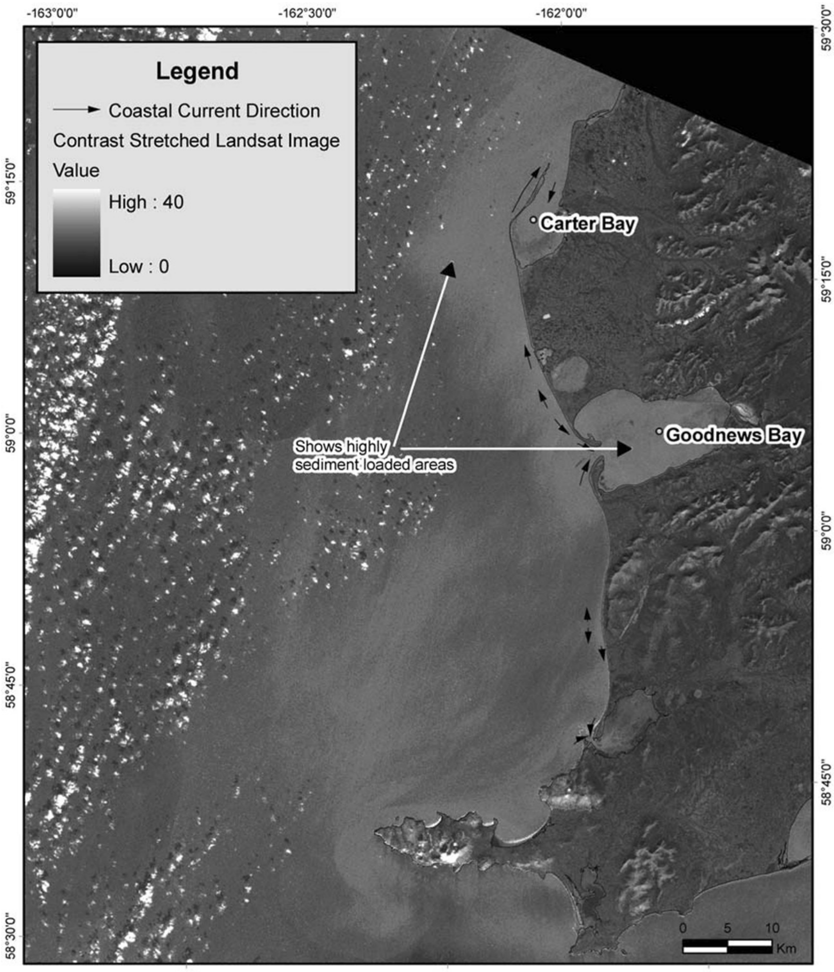


**Figure 9.** Landsat image enhanced by contrast stretching showing the sediment loaded areas, it is overlaid by the direction of longshore sediment transport due to coastal currents by USGS (Hunter et al., 1979).

the North. Earlier we had suggested that the regions of high loads of suspended sediments are local areas with intense current turbulence Thus, it is implied that the depositional pattern of Pt in the study area is influenced by hydraulic sorting of Pt-bearing particles by coastal currents.

We also examined the possibility of placer Pt concentration associated with paleo sandbars which generally have an origin in high energy environment such as a beach. The spatial distribution pattern of Pt and the sand bars observed in the study area is shown in Figure 10. Out of the four sand bars identified in the study area, the one in the north closer to the shoreline shows some promising Pt deposits. The other three sand bars do not show sufficient evidence for lag deposits. This could be because of either insufficient data from areas close to these sand bars or burial of the lag deposits by modern sediments.

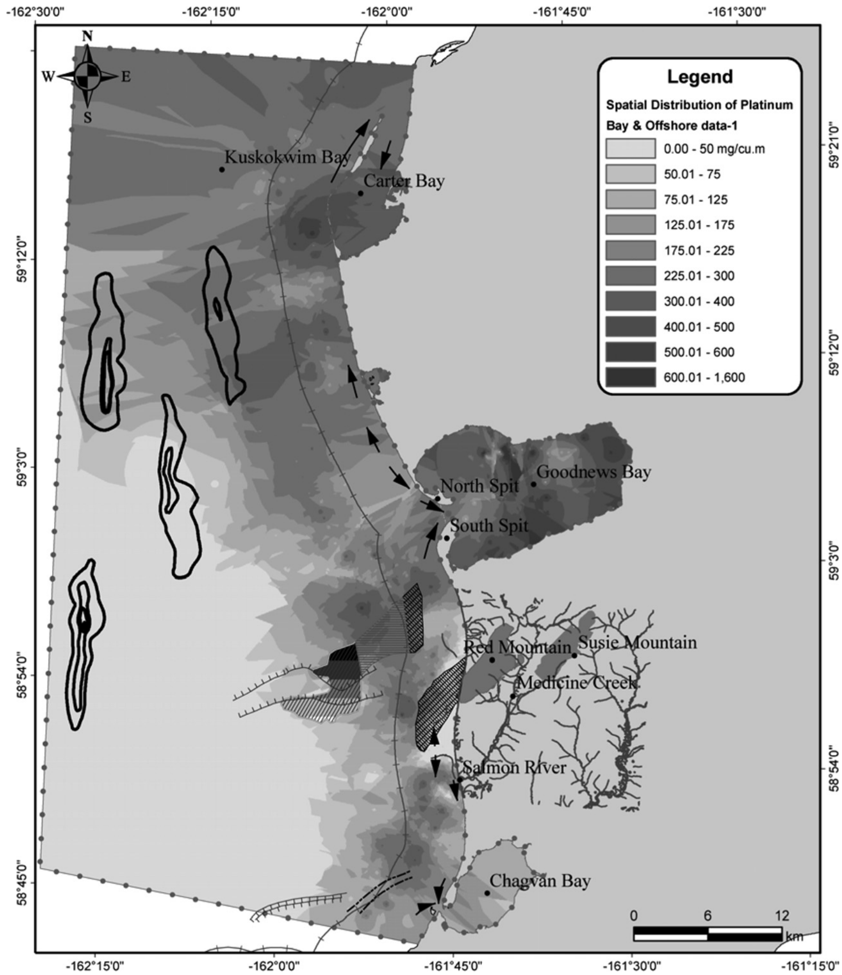


**Figure 10.** A comparison of the spatial distribution of platinum with possible drowned ultramafic rocks, paleochannels, coastal current direction and sand bars.

## Conclusions

To assess the marine Pt placer resource potential for the Goodnews Bay offshore, a geodatabase was developed by integrating all relevant data available for the region. The analysis of the geophysical data (both seismic and magnetic) identified drowned ultramafics and adjacent to it two paleochannels (possible ancient analog of the present Salmon River entrained with Pt placer) (Figure 11: inset 1 and 2). These deeply buried paleochannels are potential areas for Pt placer concentrates.

The spatial distribution of Pt indicates relatively elevated concentrations of Pt at two locations, proximal to Carter Bay and Goodnews Bay (Figure 11: inset 3 and 4). High Pt concentrations coinciding with dense suspended sediment plume suggests that the two areas are local high energy environments characterized by intense coastal and tidal currents, conducive for hydraulic sorting and concentration of Pt

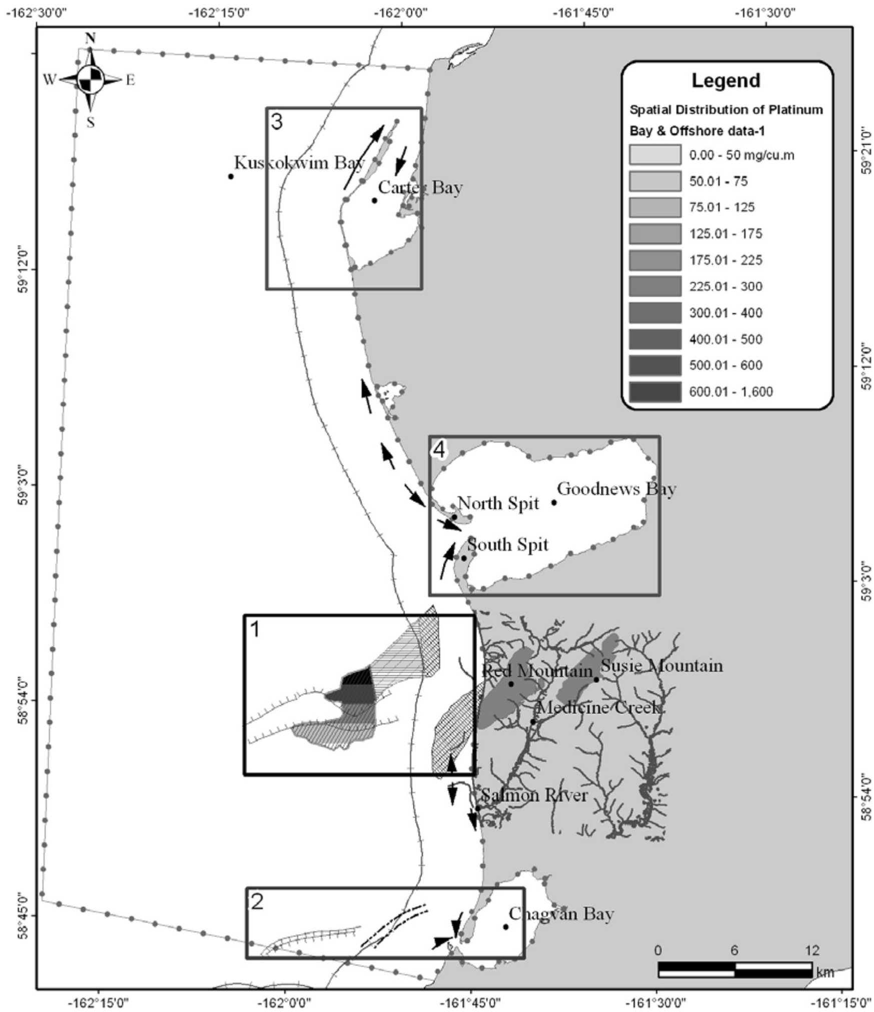


**Figure 11.** Map showing the potential locations of platinum in the study area for future exploration.

grains supplied from the Red Mountain hinterland. The study also highlights the importance of integrated analysis in a GIS environment for exploration of marine placer resource.

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