Magnetic susceptibilities measured on rocks of the upper Cook Inlet, Alaska

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Abstract

We have measured magnetic susceptibility in the field on most of the geologic rock formations exposed in the upper Cook Inlet near Anchorage and Kenai, Alaska. Measured susceptibilities range from less than our detection limit of 0.01 x 10^{-3} (SI) to greater than 100 x 10^{-3} (SI). As expected, mafic igneous rocks have the highest susceptibilities and some sedimentary rocks the lowest. Rocks of the Tertiary Sterling Formation yielded some moderate to high susceptibility values. Although we do not have detailed information on the magnetic mineralogy of the rocks measured here, the higher susceptibilities are sufficient to explain the magnitudes of some short-wavelength aeromagnetic anomalies observed on recent surveys of the upper Cook Inlet.

Introduction

The Cook Inlet Basin is a complex structural region. It is a deformed forearc basin, bounded by the Border Ranges fault to the east, and the Castle Mountain and Bruin Bay faults to the north and west (Kirschner and Lyons, 1973; Haeussler and others, 2001). The thick package of upper Mesozoic and Cenozoic sediments that fills the basin were faulted and folded under northwest-southeast regional contraction. Aeromagnetic surveys, compiled and analyzed by the U.S. Geological Survey (Saltus and others, 2001), show abundant linear, short wavelength magnetic anomalies in the upper Cook Inlet Basin (Figures 1 and 2). These anomalies are generally parallel to the northeast-southwest-striking structural fabric of the region. Saltus and others (2001) postulated that these anomalies originate from truncated and folded Tertiary and Quaternary sedimentary units within the upper 800 to 4000 m of the basin.

In this investigation, magnetic susceptibility was measured at forty-eight field sites and on core from the Deep Creek borehole, to characterize the rocks of the upper Cook Inlet Basin that may be responsible for the observed aeromagnetic anomalies (Figure 2). Using susceptibility values based on the field measurements, we have constructed a magnetic model that replicates the magnitudes of some of the observed aeromagnetic anomalies.

Magnetic susceptibility data

We measured magnetic susceptibilities in the field using hand-held magnetic susceptibility meters including an older EDO K2 meter (Bruhn data) and the Kappameter KT-5 (Haeussler data) and KT-6 (Altstatt data) models produced by Geofyzika a.s. These instruments measure apparent susceptibility with an accuracy of about 1 x 10^{-5} SI. Care was taken in our measurements to place the reading face of the instrument against a flat surface of the rock being measured. However, surface roughness of the field samples will result in measurements that are lower than the true susceptibility of the rock. For example, a surface roughness of 2 mm will lower the apparent value by 15% whereas surface roughness of 6 mm will lower the apparent value by as much as 50%. Also, surficial weathering of exposed rocks could further lower the apparent susceptibility relative to the true bulk susceptibility of unweathered rocks.

Volume susceptibility is a dimensionless quantity, but the values depend on the unit system that is used. Susceptibilities are reported here in SI volume units. To convert these values to the cgs system (often used in older studies), divide by 4π (about 12.57). For example, 12.57×10^{-3} SI equals 1.0×10^{-3} cgs. Unfortunately there is some confusion in the scientific literature over the units for susceptibility, so care is required when comparing susceptibility information from multiple sources.

In general an attempt was made to make enough measurements at each site to characterize the variation in susceptibility at that site. For the Altstatt measurements on sea cliff exposures of the Sterling and Beluga formations, susceptibility measurements were made at 0.5 m intervals on traverses that ranged from a few meters to 30 m in length up section.

To categorize the magnetic susceptibility measurements we constructed a simplified stratigraphy for the upper Cook Inlet (Figure 3, Table 1). Correlation of our stratigraphic units with rock units from different geologic maps of the region (Magoon and others,1976; Winkler, 1992; and Wilson and others, 1998) is also listed. We have also categorized our samples by rock type (Table 2) based on our field identifications.

The data table (Table 3) summarizes 1292 measured susceptibilities on rocks of twenty-four formations. Susceptibilities range from less than our instrument sensitivity of 0.01×10^{-3} SI to more than 100×10^{-3} SI. A box-and-whisker plot by formation (Figure 4) gives an overview of the data grouped by rock type and age. We categorize susceptibilities less than 1×10^{-3} SI as “low”, between 1 and 10×10^{-3} SI as “moderate”, and greater than 10×10^{-3} as “high”. As expected given their greater amount of ferromagnetic and high paramagnetic minerals, the igneous rocks have the highest magnetic susceptibility on average – from moderate to high. Susceptibilities in the metamorphic rocks are variable from low (the Valdez and McHugh formations) to high (amphiboles and some dikes in the schists at Hatcher Pass). The sedimentary rocks have generally low magnetic susceptibility with the exception of the Sterling (low to high, low mean), Arkose Ridge (low to moderate, low mean) and Talkeetna (low to high, moderate mean) Formations. The Jurassic Talkeetna Formation is considered to be the magnetic basement in this region.

Characterizing the magnetic susceptibility of the Sterling Formation is particularly important because it appears to correlate with the presence of short wavelength aeromagnetic anomalies that reflect folding within the basin (Saltus and others, 2001). The Sterling Formation has a wide range of measured susceptibility (Figures 5 and 6, Table 4), but we do not know the details of the magnetic mineralogy of these rocks. In the susceptibility measurements by Altstatt we attempted to characterize rocks of the Sterling Formation by rock types that might correlate with magnetic susceptibility (Figure 6). With the possible exception of coal, the other rock types do not differ in a statistically significant way from the overall susceptibility distribution for the entire formation. We interpret this to mean that any systematic susceptibility differences by rock type, if present, are too subtle to be picked up by the limited number of samples we have measured. Although not statistically significant, there is a suggestion that massive sandstone is more magnetically susceptibile than the other rock types. It also appears that the organic rich and orange stained rock types may have lower susceptibilities than average, but, again, this is not statistically proven in our data.

Tephra layers have been studied in the Sterling and Beluga Formations on the Kenai Peninsula (Reinink-Smith, 1995). These beds, although very thin (1 to 10 cm) were found to contain titaniferous magnetite phases (Reinink-Smith, 1995). We do not have susceptibility measurements on these tephra layers.

Some early geologic investigations of the shallow Tertiary section contain information that may be pertinent to understanding the magnetic properties of the rocks. In sea cliffs in the Homer region, Adkison and others (1975) report that the Beluga and Sterling Formations consist of interbedded shale, siltstone, and sandstone with occasional iron staining and iron nodules. A preliminary study of heavy minerals in the same rocks (Biddle, 1977) found measurable quantities of the weakly magnetic mineral siderite, primarily in the upper part of the Beluga Formation rocks in the section. Biddle (1977) interpreted the siderite to be authigenic whereas other the heavy minerals were transported. A preliminary heavy mineral study on cores of the Deep Creek well (Kelley, 1973) did not report any siderite. In both of the heavy metal studies (Kelley, 1973; Biddle, 1977) the procedures specified that "tramp iron and magnetite were removed by hand magnet." We suspect these mineral phases were removed because they were sufficiently prevalent to present a problem with separating enough of the other heavy minerals that were the primary interest of the study. Thus, while we do not know anything from these studies about the relative abundance of magnetite and other iron minerals, they are probably present. On-going laboratory studies at the University of Utah should shed light on this issue.

Although the heavy mineral study procedures were not conducive to direct conclusions about magnetic minerals, they do provide some indirect information. In the Biddle (1977) study, rocks of the Sterling Formation showed a high percentage of "igneous" minerals (60% to 80% - igneous minerals defined as mainly hornblende and hypersthene but also including apatite, monazite, sphene, zircon, and rutile) relative to the Beluga Formation rocks with a higher percentage of "metamorphic" minerals (40% to 80% - metamorphic minerals defined as mainly epidote and garnet but also including andalusite, chlorite, staurolite, tourmaline, clinozoisite, kyanite, sillimanite, tremolite, and zoisite). This observation is consistent with the interpretation (Kirschner and Lyon, 1973) that the Beluga Formation sediments have their source to the southeast in the Kenai-Chugach Mountains and that the Sterling Formation sediments came from the Alaska Range to the northwest. Based on this provenance we expect that primary igneous minerals of the magnetite to ulvospinel solid-solution series form the main source for the magnetic susceptibilities of the Sterling Formation rocks.

Modeling of shallow magnetic anomalies

We generated a simple magnetic model (Figure 7) using commercial modeling software (GM-SYS from NGA, Inc.). Susceptibility variations used in the model are based on our field measurements. This observed susceptibility range was applied to an hypothetical cross-section through the upper 1.5 km of the Sterling Formation, as it may appear near the Clam Gulch area. The topography was generated to mimic the sea cliff present in that region. The resulting anomalies produced by the truncation, both in folds and by the sea cliff, of layers assigned different susceptibilities have amplitudes of 4-5 nT and wavelengths of ~500 m. The sea cliff truncation produced a distinct anomaly, similar in scale and polarity to those observed in the shortest wavelengths of the aeromagnetic data (Figure 2).

Conclusions

We measured magnetic susceptibility of many of the mapped geologic rock formations in the upper Cook Inlet region near Anchorage and Kenai, Alaska. The measurements generally fall within typical ranges for the rock types (e.g., Telford and others, 1976). For example, the igneous rocks in the study area have generally moderate to high susceptibilities, with the higher values occurring in the more mafic rocks. Metamorphic rock types have generally low to moderate susceptibilities with the exception of some highly magnetic schists. Cretaceous to Tertiary sedimentary rocks of the upper Cook Inlet have generally low susceptibility with the exception of some moderate susceptibilities measured in rocks of the Arkose Ridge formation and moderate to high susceptibilities measured in rocks of the Sterling formation. We do not, at present, know the magnetic mineralogy of any of the rocks we have studied. We suspect that most of the moderate-to-highly magnetic rocks have susceptibilities caused by titanomagnetite. The rocks with generally low susceptibilities may contain a variety of magnetic minerals, in addition to titanomagnetite, including siderite as reported previously in some rocks of the Sterling and Beluga Formations.

In general, the measured susceptibilities are consistent with the observed aeromagnetic anomalies in the region. In particular, we constructed an hypothetical magnetic model cross-section to demonstrate how truncations of magnetic layers within the Sterling Formation can give rise to some of the observed anomalies. This work supports the conclusion by Saltus and others (2001) that at least some of the short-wavelength aeromagnetic anomalies are related to the truncation or offset of magnetic layers within the shallow sedimentary rock section

Acknowledgements

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References

Adkison, W.L., Kelley, J.S., and Newman, K.R., 1975, Lithology and palynology of the Beluga and Sterling Formations exposed near Homer, Kenai Peninsula, Alaska: U.S. Geological Survey Open-file Report 75-383, 148 p.

Adkison, W.L., and Newman, K. R., 1973, Lithologic characteristics and palynology of Upper Cretaceous and Tertiary Rocks in the Deep Creek Unit Well, Kenai Peninsula, Alaska: U.S. Geological Survey Open-file Report 73-1, 271 p.

Biddle, K.T., 1977, Preliminary study of heavy minerals from the Beluga and Sterling Formations exposed near Homer, Kenai Peninsula, Alaska: U.S. Geological Survey Open-file Report 77-874, 12 p.

Bruhn, R.L., Parry, W.T., and Bunds, M.P., 2000, Tectonics, fluid migration, and fluid pressure in a deformed forearc basin, Cook Inlet, Alaska: Geological Society of America Bulletin, v. 112, n. 4, p. 550-563.

Haeussler, P.J., Bruhn, R.L., and Pratt, T.L., 2000, Potential seismic hazards and tectonics of the upper Cook Inlet basin, Alaska, based on analysis of Pliocene and younger deformation: Geological Society of America Bulletin, v. 112, n. 9, p. 1414-1429.

Kelley, J.S., 1973, Preliminary study of the heavy minerals from cores of Tertiary rocks in the Deep Creek Unit well, Kenai Peninsula, Alaska: U.S. Geological Survey Open-File Report 73-141, 9 p.

Kirschner, C.E., and Lyon, C.A., 1973, Stratigraphic and tectonic development of Cook Inlet petroleum province: in Arctic Geology, American Association of Petroleum Geologists Memoir 19, p. 396-407.

Magoon, L.B., Adkison, W.L., and Egbert, R.M, 1976, Map showing geology, wildcat wells, Tertiary plant fossil localities, K-Ar age dates, and petroleum operations, Cook Inlet area, Alaska: U.S. Geological Survey Map I-1019, scale 1:250,000, 3 sheets.

Reinink-Smith, Linda M., 1995, Tephra layers as correlation tools of Neogene coal-bearing strata from the Kenai lowland, Alaska, Geological Society of America Bulletin v. 107, p. 340-353.

Saltus, R.W., Haeussler, P.J., Bracken, R.E., Doucette, J.P., and Jachens, R.C., 2001, Anchorage Urban Region Aeromagnetics (AURA) Project – Preliminary Geophysical Analysis: U.S. Geological Survey Open-file Report 01-0085 (http://geology.cr.usgs.gov/pub/open-file-reports/ofr-01-0085/).

Telford, W.M., Geldart, L.P., Sheriff, R.E., and Keys, D.A., 1976, Applied Geophysics: Cambridge University Press, New York, 860 pp.

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K, and Haeussler, P.J., 1998, Geologic map of central (interior) Alaska: U.S. Geological Survey Map OFR-98-0133, scale 1:500,000, 3 sheets and 76 p.

Winkler, G.R., 1992, Geologic map and summary geochronology of the Anchorage 1°x3° quadrangle, southern Alaska: U.S. Geological Survey Map I-2283, scale 1:250,000, 1 sheet.

		Winkler, 1992 Map I-2283				Altstatt and others, 2002 This report	
		Symb	Formation name			Symb	
		Qs	Surficial deposits			Qs	
Tks	Sterling				Sterling	Tks	Sterling
Tkb	Beluga			Tkb	Beluga	Tkb	Beluga
Tkt	Tyonek	Ttk	Tyonek	Tty	Tyonek	Tkt	Tyonek
Tkh	Hemlock					Tkh	Hemlock
Tt	Tsadaka	Tt	Tsadaka	Tts	Tsadaka	Tt	Tsadaka
Twf	West Foreland			Twf	West Foreland	Twf	West Foreland
Tw	Wishbone	Tw	Wishbone	Tw	Wishbone	Tw	Wishbone
Tc	Chickaloon	Tc	Chickaloon	Tch	Chickaloon	Tc	Chickaloon
Tar	Arkose Ridge	Tar	Arkose Ridge	Tar	Arkose Ridge	Tar	Arkose Ridge
Kk	Kaguyak						
Km	Matanuska	Km	Matanuska	Km	Matanuska	Km	Matanuska
Jn	Naknek	Jn	Naknek	Jn	Naknek	Jn	Naknek
Jc	Chinitna	Jc	Chinitna	Jc	Chinitna	Jc	Chinitna
Jt	Tuxedni	Jt	Tuxedni	Jtx	Tuxedni	Jt	Tuxedni
Jtk	Talkeetna	JTrt	Talkeetna	JTrtk	Talkeetna	JTrt	Talkeetna
Trk	Kamishak						
Trb	Limestone of Bruin Bay	Trl	Limestone	Trlb	Limestone & basalt		
Metamorphic Rocks							
KJv	Valdez	Kvs	Valdez meta seds	Kvs	Valdez meta seds	Kvs	Valdez meta seds
		Kvt	Valdez meta volcs	Kvv	Valdez meta volcs	Kvt	Valdez meta volcs
KJm	McHugh	MzM	McHugh	KTrm	McHugh	KTrm	McHugh
MzPzs	Schist at Willow Creek	Jps	Pelitic schist	Mzsa	Schist & amphibole	Mzsa	Schist & amphibole
				Jps	Pelitic schist		
Jpu	Metamorphic, undivided	JPzm	Metamorphic, undiv			JPzm	Metamorph, undif.
Felsic Plutonic & Hypabyssal Rocks							
Tg	Granite	Ti	Hyp. Felsic & int.	Thf	Hyp. Felsic and intermediate		
Tgd	Granodiorite			Thgd	Hyp. Granodiorite and int.		
		TKg	Granite	TKg	Granite	TKg	Granite
TKgd	Granodiorite			TKgd	Granodiorite	TKgd	Granodiorite
		TKt	Tonalite				
		Kw	Willow Crk pluton				
		Kt	Leucotonalite & trondhj.				
				Kg	Granite		
Kg	Quartz monzonite						
		Jtr	Trondhjemite				
Jg	Quartz monzonite					Jg	Granite
Jgd	Granodiorite & diorite	Jgd	Granodiorite			Jgd	Granodiorite
		Jqd	Quartz diorite				
		Jqt	Qtz diorite & tonalite				
Mafic Plutonic & Hypabyssal Rocks							
		Tim	Hyp. Mafic intrus.	Thm	Hyp. Mafic intrusive	Tds	Tertiary dikes & sills
		TJds	Mafic dikes and sills			TJds	mafic dikes & sills
		Kum	Serpentinized u. mafics				
		Jmip	Mafic & int. plutonic rx				
		Jgd	Gabbronorite				
		Jgs	Sheared gabbronorite				
Jm	Mafic & ultramafic	Jum	Ultramafic & mafic	Jmu	Mafic & ultramafic	Jmu	mafic & ultramafic
Trm	Mafic rocks						
				Mzi	Intrusive rocks		
MzPzm	Gabbroic rocks			MzPzi	Intrusive and volcanics		
MzPzu	Ultramafic rocks						
Volcanic & Shallow Intrusive Rocks							
						Qvs	Volcanic seds
Qv	Volcanic rocks			Qv	Volcanic rocks	Qv	Volcanic rx
Tv	Volcanic rocks	Tv	Volcanic	Tvu	Volcanic rocks	Tv	Volcanic rx
Ti	Intrusive rocks			Tiv	Granitic and volcanic	Ti	Intrusive

Table 1. Stratigraphic formation names and map codes, upper Cook Inlet, Alaska.

	Rock type
	amphibolite
	andesite
	beach cobbles
C	coal
CC	carbonate cement
CG	conglomerate
DR	diorite
FLS	felsic sill
FSD	feldspathic dike
GN	gneiss
GR	granite
GRD	granodiorite
GS	greenschist
GW	graywacke
MAN	meta andesite
MB	marble
ME	melange
MFD	mafic dike
MFS	mafic sill
MGW	meta graywacke
MS	mudstone
MT	metamorphic
MTB	meta turbidite
QZ	quartzite
SCH	schist
SPR	serpentinized peridotite
SH	shale
SRP	serpentinite
SS	sandstone
TB	turbidite
VD	dark volcanic
VF	felsic volcanic

Table 2. Rock type categories and abbreviations used in this study.

TYPE	FM	N	MEAN	STD	SEM	MIN	MAX
Volcanic	Qv	42	10.13	6.54	1.01	2.43	28.60
	Qvs	19	17.36	8.89	2.04	5.00	34.70
	Tv	3	0.15	0.03	0.02	0.12	0.18
	Ti	18	4.38	2.40	0.57	1.88	8.56
Plutonic	TKg	105	7.58	7.50	0.73	0.01	40.90
	TKgd	59	8.05	9.63	1.25	0.25	45.90
	Jg						
	Jgd	26	5.33	5.44	1.09	0.13	13.80
	Tds	8	29.19	12.38	4.38	19.80	57.40
	TJds						
	Jmu	7	25.77	17.54	6.63	10.60	49.40
	MzPzm						
	MzPzum	21	47.21	35.90	7.83	10.43	110.58
Metamorphic	Kvs	18	0.23	0.08	0.02	0.05	0.37
	Kvt						
	KTrm	49	0.34	0.19	0.03	0.05	0.63
	Mzsa	31	13.02	20.17	3.62	0.63	83.40
	JPzm	70	1.92	3.76	0.45	0.01	18.60
Sedimentary	Qs						
	Tks	329	1.32	2.73	0.15	0.02	35.90
	Tkb	270	0.18	0.15	0.01	0.01	1.01
	Tkt	54	0.37	0.12	0.02	0.12	0.59
	Tkh	4	0.19	0.07	0.03	0.13	0.25
	Tt						
	Twf	10	0.43	0.22	0.07	0.13	0.75
	Tw	12	0.28	0.06	0.02	0.17	0.38
	Tc	17	0.37	0.21	0.05	0.13	0.88
	Tar	26	1.23	1.34	0.26	0.25	4.94
	Km	13	0.48	0.27	0.08	0.13	1.13
	Jn						
	Jc						
	Jt						
	JTrt	81	5.99	7.86	0.87	0.06	37.90

Susceptibilities in SI x 10-3

Susceptibility color scale:

- High > 10
- Moderate > 1
- Low >.1
- Non-magnetic <.1

Table 3. Summary table for measured magnetic susceptibilities by geologic formation, upper Cook Inlet, Alaska.

```
WINKS 4.65                                                  January 25,2002
---------------------------------------------------------------------------
Descriptive Statistics
---------------------------------------------------------------------------
Variable Name is K (susceptibility in SI x 10-3)

N         = 318                   Missing or Deleted = 0
Mean      = 1.35                       St. Dev (n-1) = 2.77
Median    = 0.57                         St. Dev (n) = 2.76
Minimum   = 0.02                              S.E.M. = 0.15
Maximum   = 35.90                          Variance  = 7.67
                                          Coef. Var. = 2.04
---------------------------------------------------------------------------
Percentiles:                                Tukey Five Number Summary:
0.0%          = 0.02    Minimum             Minimum  = 0.02
0.5%          = 0.0319                      Fourth   = 0.35
2.5%          = 0.15975                     Median   = 0.57
10.0%         = 0.25                        Fourth   = 1.71
25.0%         = 0.35    Quartile            Maximum  = 35.90
50.0%         = 0.57    Median
75.0%         = 1.71    Quartile
90.0%         = 2.576
97.5%         = 4.14325
99.5%         = 28.58152                    Test for normality results:
100.0%        = 35.90   Maximum             D = .317     p <= 0.001

Five number summary was calculated using the technique from UNDERSTANDING
ROBUST AND EXPLORATORY DATA ANALYSIS by Hoaglin, Mosteller And Tukey.

Confidence Intervals about the mean:
---------------------------------------------------------------------------
80 % C.I. based on a t critical value of 1.28 is (1.15, 1.55)
90 % C.I. based on a t critical value of 1.64 is (1.09, 1.60)
95 % C.I. based on a t critical value of 1.96 is (1.04, 1.65)
98 % C.I. based on a t critical value of 2.32 is (0.99, 1.71)
99 % C.I. based on a t critical value of 2.57 is (0.95, 1.75)

The normality test suggests that the data are not normally distributed.
```

Table 4. Detailed statistics for measured magnetic susceptibilities in rocks of the Sterling formation, upper Cook Inlet, Alaska.

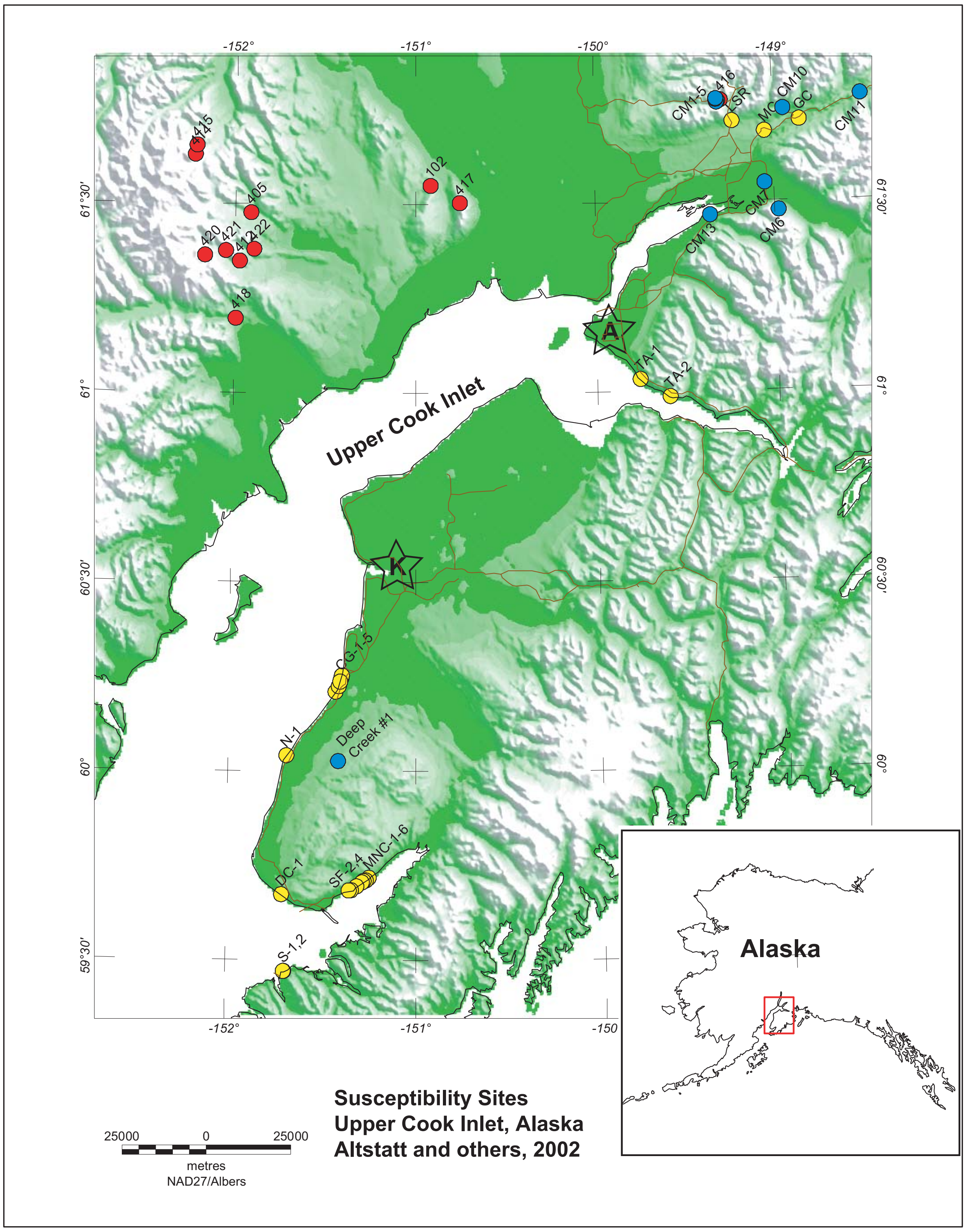

Figure 1. Location map of the upper Cook Inlet including susceptibility measurement sites. Yellow circles indicate sites measured by Altstatt, red circles indicate Haeussler data sites, blue circles indicate Bruhn data sites. Towns: A, Anchorage; K, Kenai.

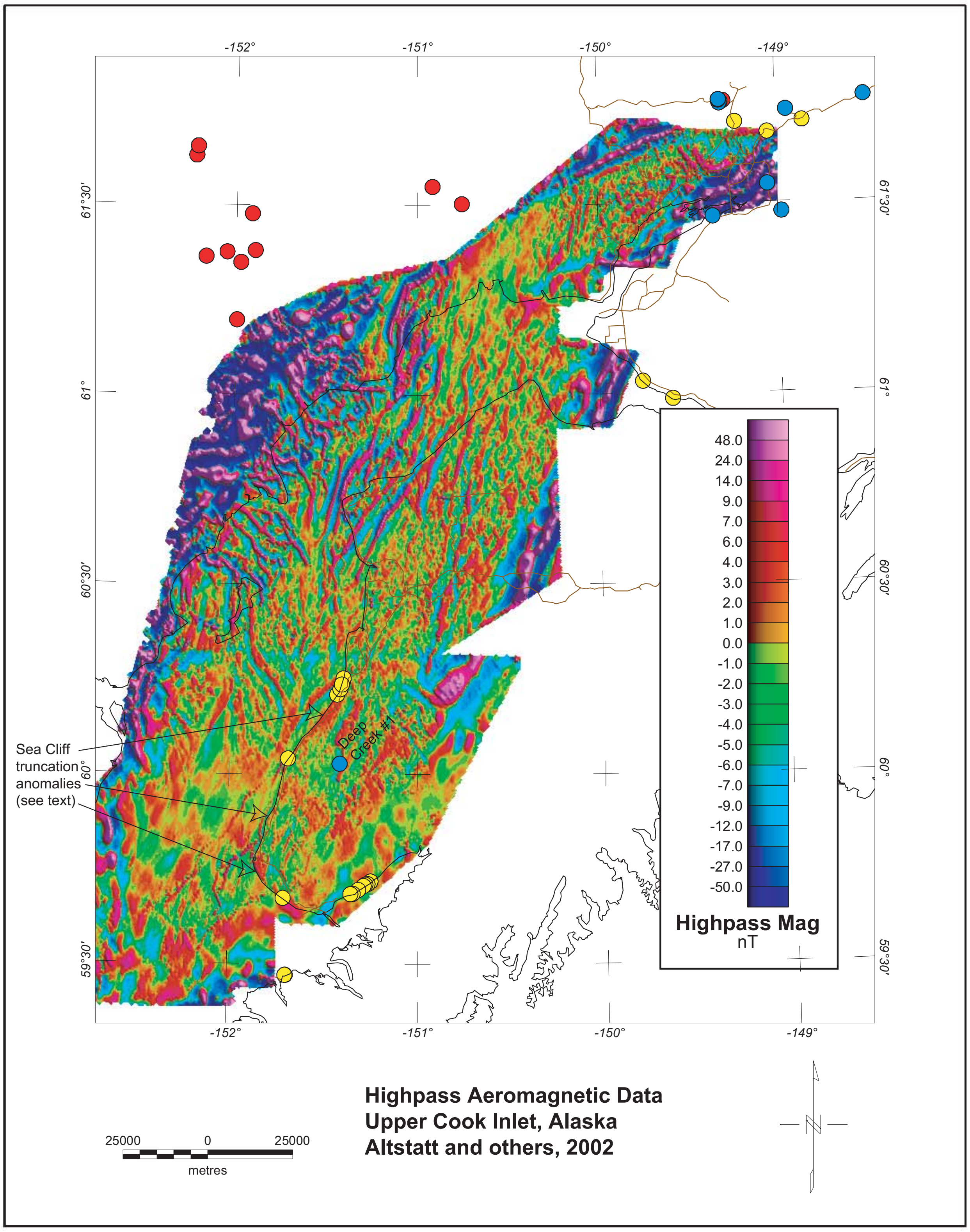

Figure 2. Short-wavelength (shallow source) aeromagnetic anomalies of the Anchorage and Kenai area. Anomalies were mathematically filtered by Saltus and others (2001) using proprietary data obtained under contract by the U.S. Geological Survey from Fugro Airborne Surveys, Corp. Circles are magnetic susceptibility sites as in Figure 1.

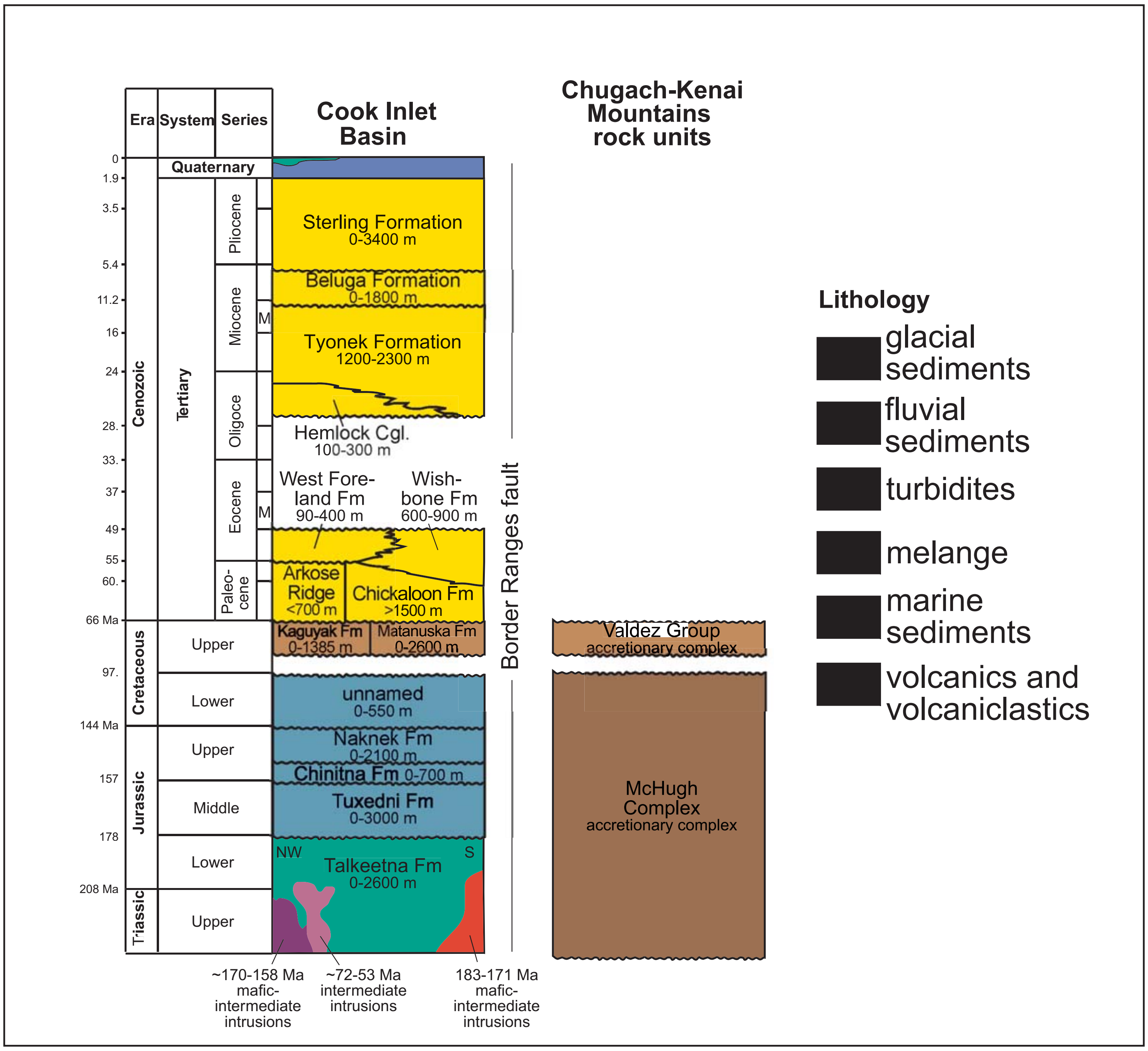

Figure 3. Simplified stratigraphic column for the upper Cook Inlet, Alaska. See Table 1 for the symbol codes used for these formations in our data tables. Note that some of the preTertiary units have undergone low-grade metamorphism.

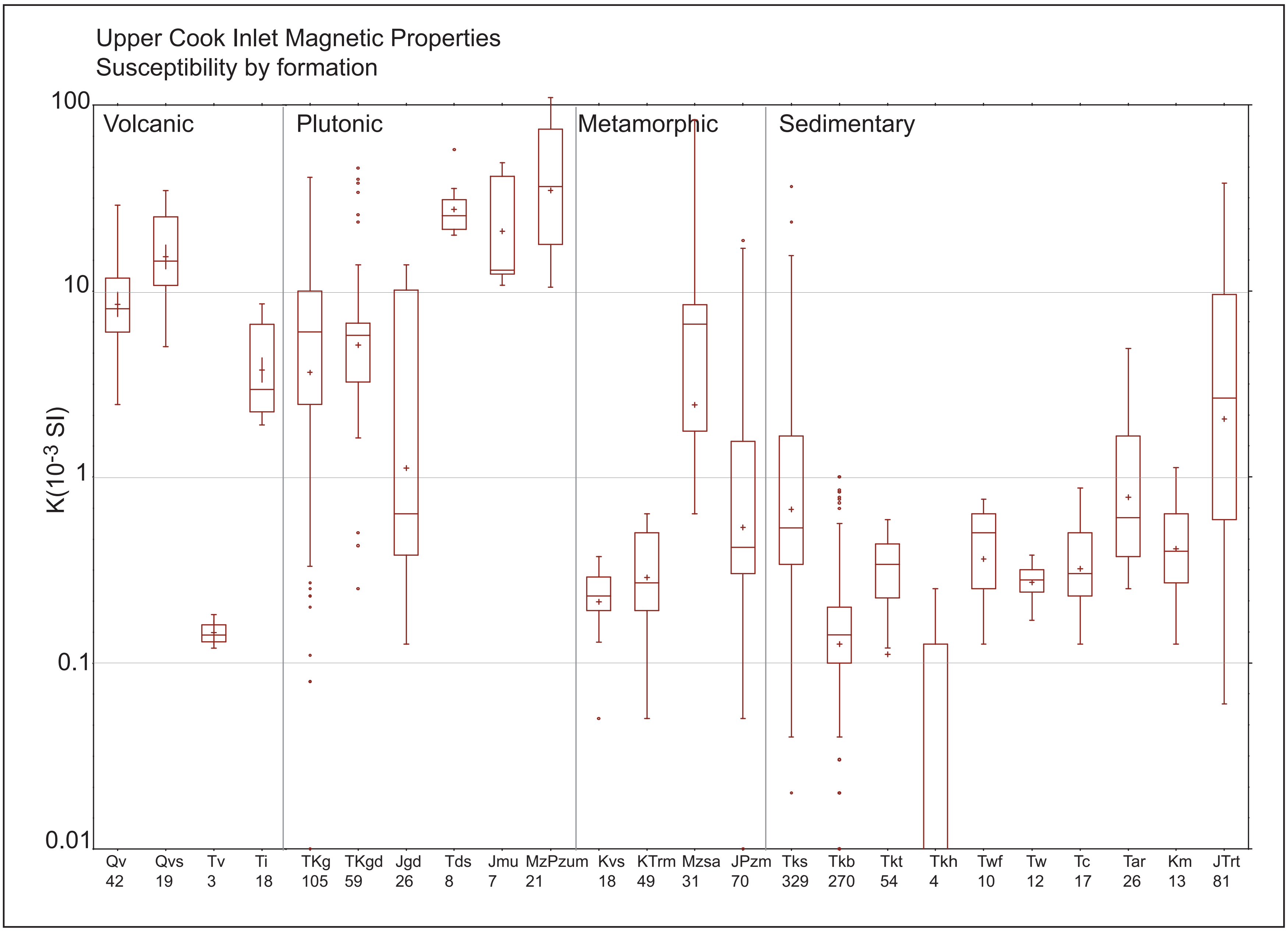

Figure 4. Summary plot for magnetic susceptibility by geologic formation, grouped by broad rock type, upper Cook Inlet, Alaska. The central "+" indicates the mean value of the data for that rock formation. The box depicts values between the 25th and 75th percentiles. The center bar in the box shows the median value. The whisker ends show the full range of the data, not counting outliers. Small pluses indicate data points identified as outliers because they fall outside a smooth histogram of the data values. This plot was developed using the WINKS 4.6 statistical analysis package by TexaSoft. The numbers beneath the geologic formation codes are the total number of susceptibility measurements for each formation.

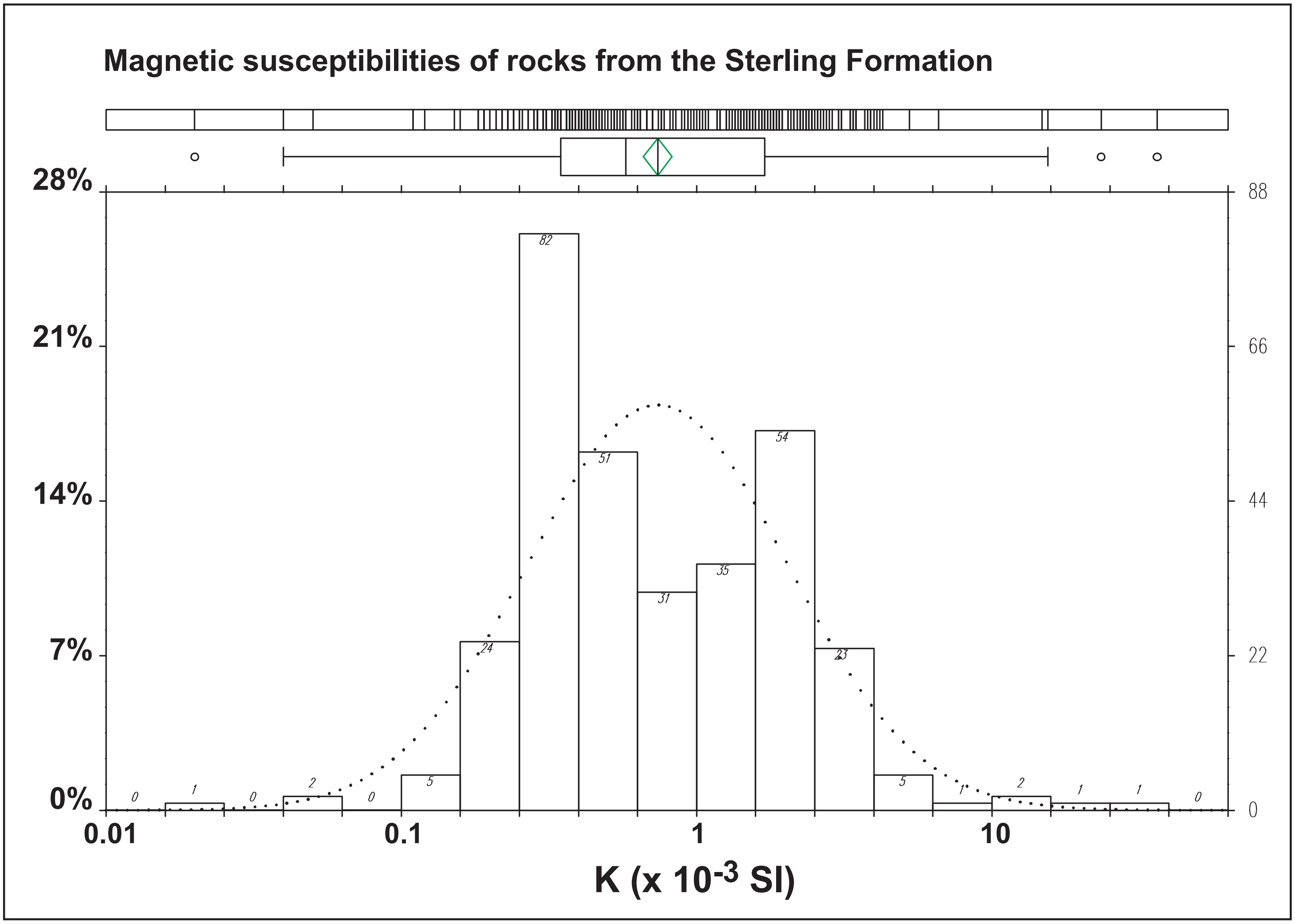

Figure 5. Histogram for magnetic susceptibility measurements in rocks of the Sterling Formation, upper Cook Inlet, Alaska. The uppermost bar depicts all the susceptibility measurements for this formation as vertical lines. The box-and-whisker plot beneath it shows the normal data range, 25th, 50th, 75th percentile, and outliers as discussed in the caption for Figure 4. The green diamond symbol shows the average data value. The histogram boxes show the data population. Each box is labeled with the number of data points in that interval. An equivalent log normal data distribution curve is also plotted for reference. There is some indication of a bimodal distribution to these data (i.e., two separate peaks in the histogram). If real, this could indicate that there are two independent distributions of magnetic minerals, possibly related to different rock types within the Sterling formation. See Table 4 for tabulations of the susceptibility statistics for this formation.

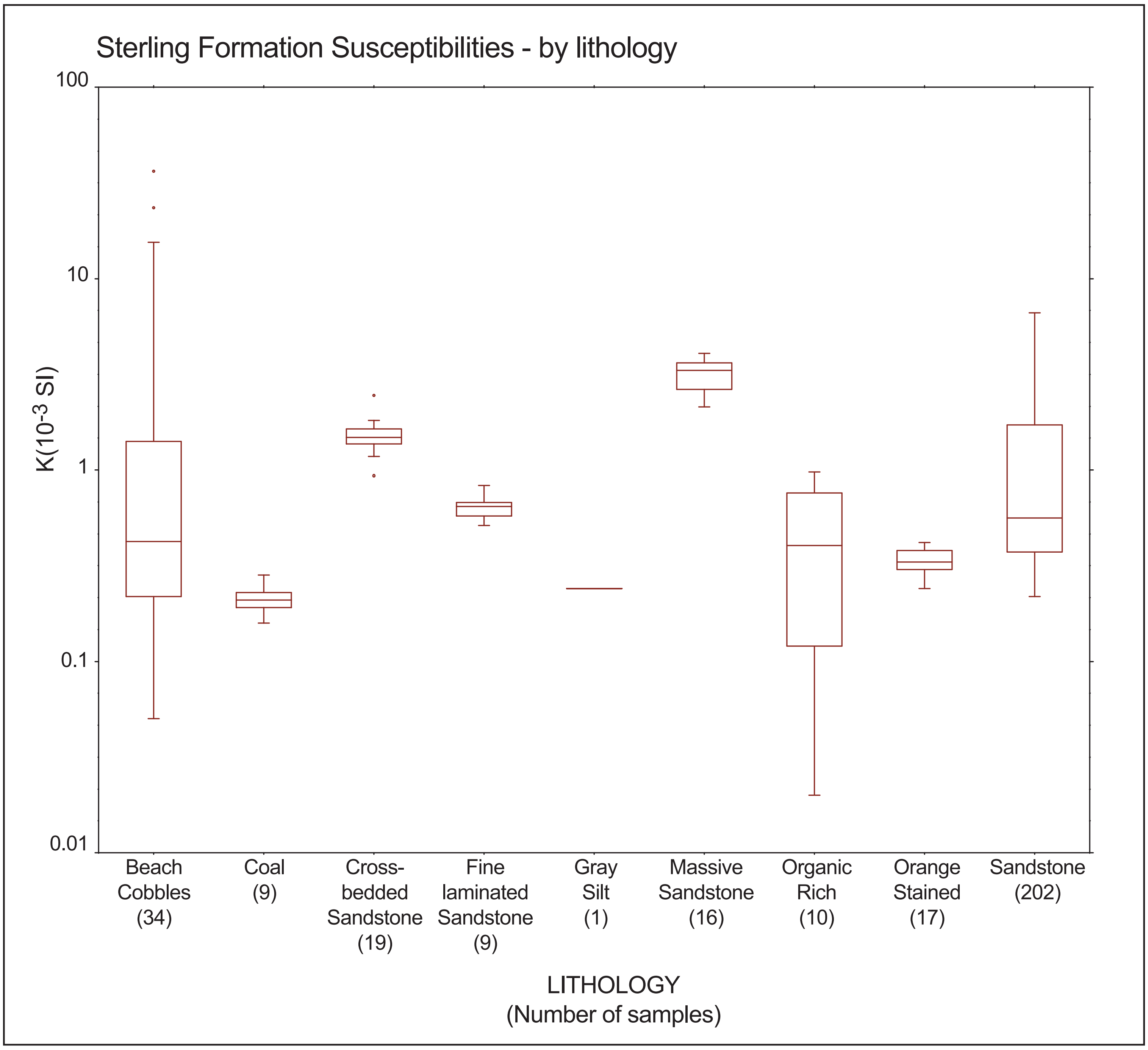

Figure 6. Magnetic susceptibilities measured on rocks of the Sterling Formation, subdivided by rock type. With the exception of "coal", none of the individual rock type distributions differ in a statistically significant way from the average distribution.

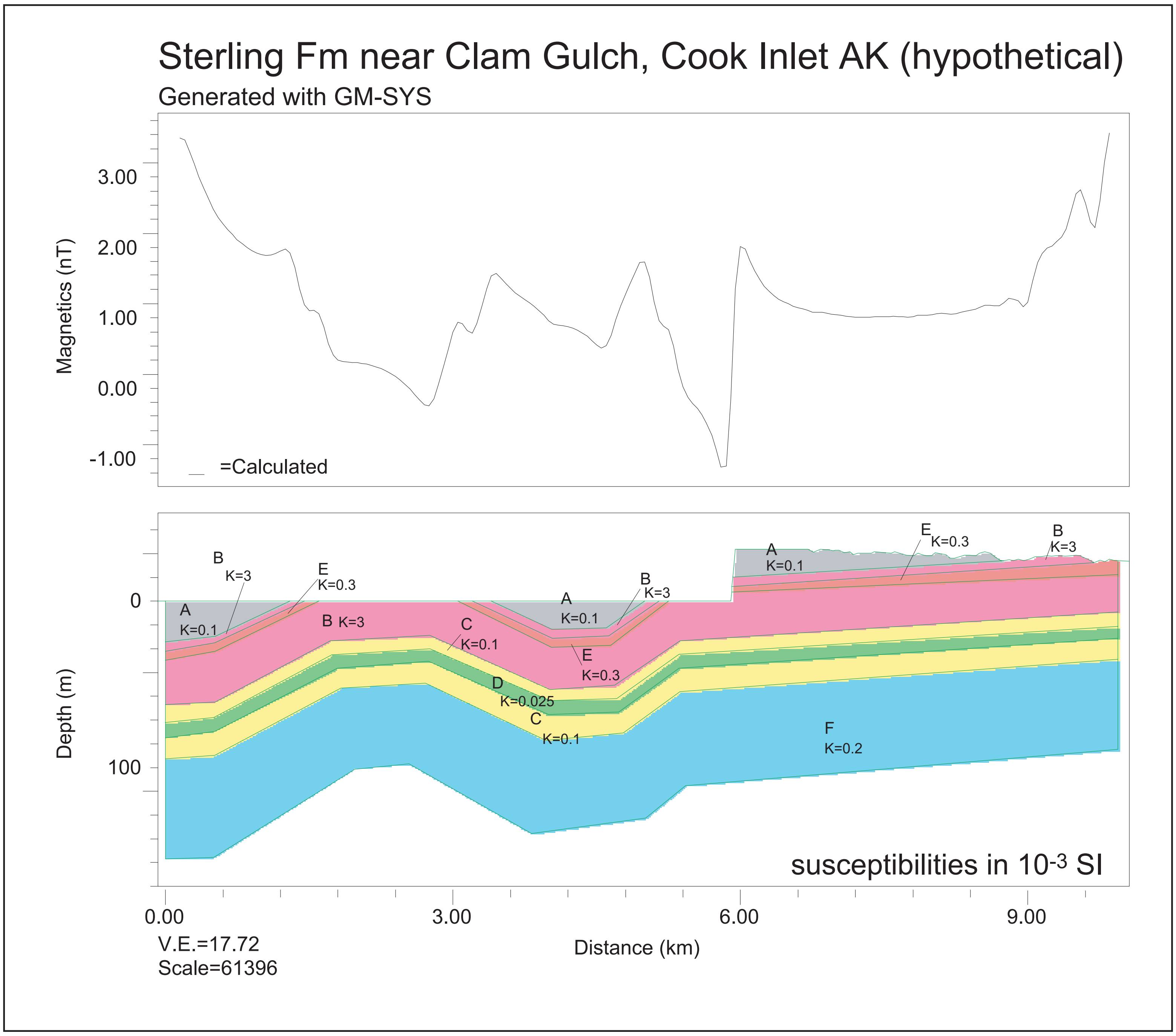

Figure 7. Hypothetical magnetic model cross-section to illustrate viability of producing observed short-wavelength aeromagnetic anomalies with susceptibilities consistent with field measurements. The K values are susceptibilities in 10^{-3} SI. Layer thicknesses are based on observed variations in susceptibility at measurement sites in this region. This model was created using the GM-SYS program by NGA, Inc.

APPENDIX

llowing data directories contain auxiliary information related to this report.

DATA – Excel spreadsheets of magnetic susceptibility data.
See README file in the directory for more information.
ftp://geology.cr.usgs.gov/pub/open-file-reports/ofr-02-0139/DATA/

PHOTOS – Field photos from magnetic susceptibility measuring sites.
See README file in the directory for more information.
ftp://geology.cr.usgs.gov/pub/open-file-reports/ofr-02-0139/PHOTOS/

MAPS – Field location maps for some of the magnetic susceptibility measuring sites.
See README file in the directory for more information.
ftp://geology.cr.usgs.gov/pub/open-file-reports/ofr-02-0139/MAPS/