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Principal facts for gravity data collected in the northern Susitna Basin area, southcentral Alaska

by
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INTRODUCTION

In order to help stimulate interest in the Susitna basin for petroleum exploration, the Division of Oil and Gas (DO&G) has been collecting regional gravity data throughout the area to complement and extend the gravity data that is currently available from the U.S. Geological Survey (USGS). During the summer of 2000, DO&G collected readings from 120 gravity stations along profiles in the southern portion of the basin (Meyer and Boggess, 2003). The current project was designed to obtain data from 90 additional gravity stations to extend these profiles and create new profiles in the northern portion of the basin. The gravity stations collected are primarily located in the Talkeetna Quadrangle and the northwest corner of the Tyonek Quadrangle 1:250,000-scale USGS topographic maps. The study area is bounded approximately by 61°50’ to 62°30’N latitude and 151°00’ to 152°30’W longitude. Figure 1 is a map of the Susitna basin showing the newly collected gravity stations in addition to the previously collected gravity stations that are currently available from the USGS.

The Susitna basin is a topographic lowland encompassing an area of approximately 4,700 square miles, bordered by the Alaska Range on the north, the Talkeetna Mountains on the east, the Tordrillo Mountains on the west and the Cook Inlet basin on the south. The Susitna basin is considered a northern extension of the Cook Inlet basin, separated from it by the Castle Mountain fault, a major regional structural feature of southcentral Alaska.

The depositional history of the region started during the late Paleozoic and early Triassic when marine sediments were deposited throughout the area. This was followed by a time of deformation and uplift during the late Triassic, which resulted in the deposition of sediments in the Cook Inlet basin to the south. Uplift and erosion of the Alaska Range during the Cretaceous through Tertiary provided the material for a thick sequence of continental shelf deposits throughout the region that were composed of fine-grained sediments rich in organic material. During the Tertiary period, a repetitive cycle of vegetative growth and sediment deposition occurred, depositing sediments along with conglomerates, sands, and clays that created numerous peat layers that were buried, producing the present-day coal formations. The adjacent sands and gravels deposited in the region have become potential reservoirs for oil and gas in the area (Selkregg, 1974; Tim Ryherd, oral commun., 2003). Based on scattered well data in the southern portion of the basin, including the Farms Red Shirt Lake #1 and Inlet Oil Fish Creek #1 wells, the region is believed to be underlain by granitic basement rock that is continuous with the Tertiary–Cretaceous age granitic batholith of the Talkeetna Mountains (Turner and Wescott, 1982).

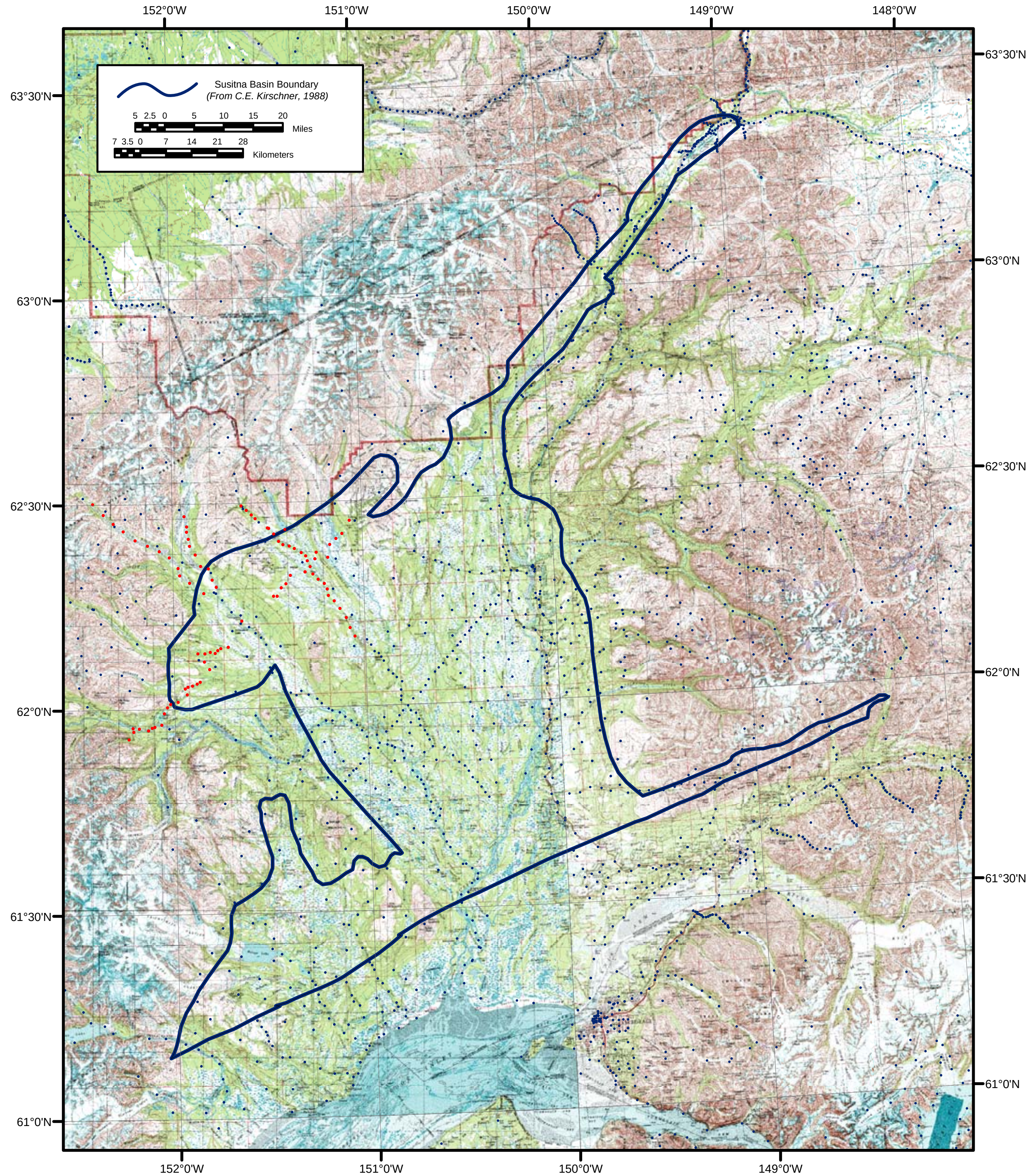

Figure 1. Index map of the study area showing the locations of the gravity data collected for this study (in red). The previously collected data is shown in black. The map base is a composite of USGS 1:250,000-scale topographic maps.

The structural style of the basin is a combination of graben and half-graben basement faulting with Tertiary sedimentary fill consisting of some of the same formations as found in the Cook Inlet basin. The sedimentary section ranges from about 2,000 feet thick just north of the Castle Mountain Fault to more than 13,000 feet in the center of the basin, while south of the fault it is estimated to be at least 20,000 feet thick (Maynard, 1987; Ryherd, oral commun., 2003). The Eocene-age West Foreland Formation and Oligocene age Hemlock Conglomerate reservoir rocks that are found to the south in the Cook Inlet basin appear to be missing in this basin. The presence of dry gas source rocks in the region, similar to those found in the Cook Inlet basin, and the apparent absence of equivalent oil-prone source rocks indicate that the potential for finding gas in the basin is much greater than for finding oil within the Tertiary section. Coal seams are thick and numerous in parts of the basin, and provide targets for methane drainage drilling as well as a source for gas to charge conventional sandstone reservoirs.

The Susitna basin has not been extensively explored, although a number of oil and gas exploration wells and core tests have been drilled in the region. All of these wells were plugged and abandoned as dry holes, although some did have minor gas shows. There were also prominent coal beds in the lower part of some of the wells, suggesting a correlation with the coal-bearing formations in the Cook Inlet basin that produce natural gas. Taking this into account, the petroleum potential of the basin is thought to be low to moderate (Ryherd, oral commun., 2003).

GRAVITY-DATA ACQUISITION AND REDUCTION

A LaCoste and Romberg gravity meter (G507) was used to collect the new gravity station data. Conversion of the meter readings to milligals was made using factory calibration constants and a calibration factor determined by Dave Barnes of the USGS. During the field surveys, the gravity meter appeared to function properly, and an average drift of .008 mgal/day with a maximum drift of 0.1 mgal/day indicates there were no apparent tares in the data. The observed gravity values were based on an assumed linear drift between base station readings throughout the day.

Datum control for all of the gravity values was provided by the USGS Alaskan Gravity Base Station Network (Barnes, 1968; 1972) and was adjusted to the new absolute datum of the International Gravity Standardization Net 1971 (Morelli and others, 1974). A second-order base station, CHLK, was also created at Cabin 1 of the Chelatna Lake Lodge to replace the old CHEL base station that was destroyed during construction. The observed gravity of the CHLK station was calculated based on multiple ties to the established TLKM base station. For the duration of the survey, this new base station was reoccupied seven times with survey loops limited to 8 hours or less.

Horizontal control was obtained using a Trimble GeoExplorer 3 handheld Global Positioning System (GPS) unit and 1:63,360-scale USGS topographic maps. The station sites were located on USGS topographic maps in the field and digitized for comparison to the reduced GPS data. The GPS locations were processed using the Trimble GPS Pathfinder Office software and base station data obtained from the NOAA Continuously Operating Reference Stations (CORS) in Talkeetna and Anchorage. Standard processing techniques were applied to the GPS data by averaging the corrected data after applying differential corrections and selecting the best-corrected locations within the 68 percent confidence level. The accuracies for the corrected GPS locations were found to be ±2 feet, and in all but a few cases were found to be of a higher accuracy, compared to the digitized locations. In a few cases, the GPS base station data did not contain enough information to get reasonable locations and the digitized values were used.

Vertical control was obtained using a Trimble GeoExplorer 3 handheld GPS unit, American Paulin Model T-5 altimeters and USGS topographic maps at a scale of 1:63,360. The altimetry data was collected using three Paulin altimeters with the readings averaged at each station and corrected for diurnal barometric variations. Where feasible, the gravity stations were located at U.S. Coast and Geodetic Survey Vertical Angle Benchmarks (VABM) for comparison. Temperature and drift corrections were also applied and yielded elevations with an accuracy of ±30 feet. Elevations were also digitized from USGS topographic maps with an accuracy of ±50 feet and the GPS data were processed as described above and yielded data with an accuracy of ±2 feet. A comparison of the three elevations was made (fig. 2) and it was determined that for most of the stations, the GPS values provided the most accurate and consistent values for use in reducing the data.

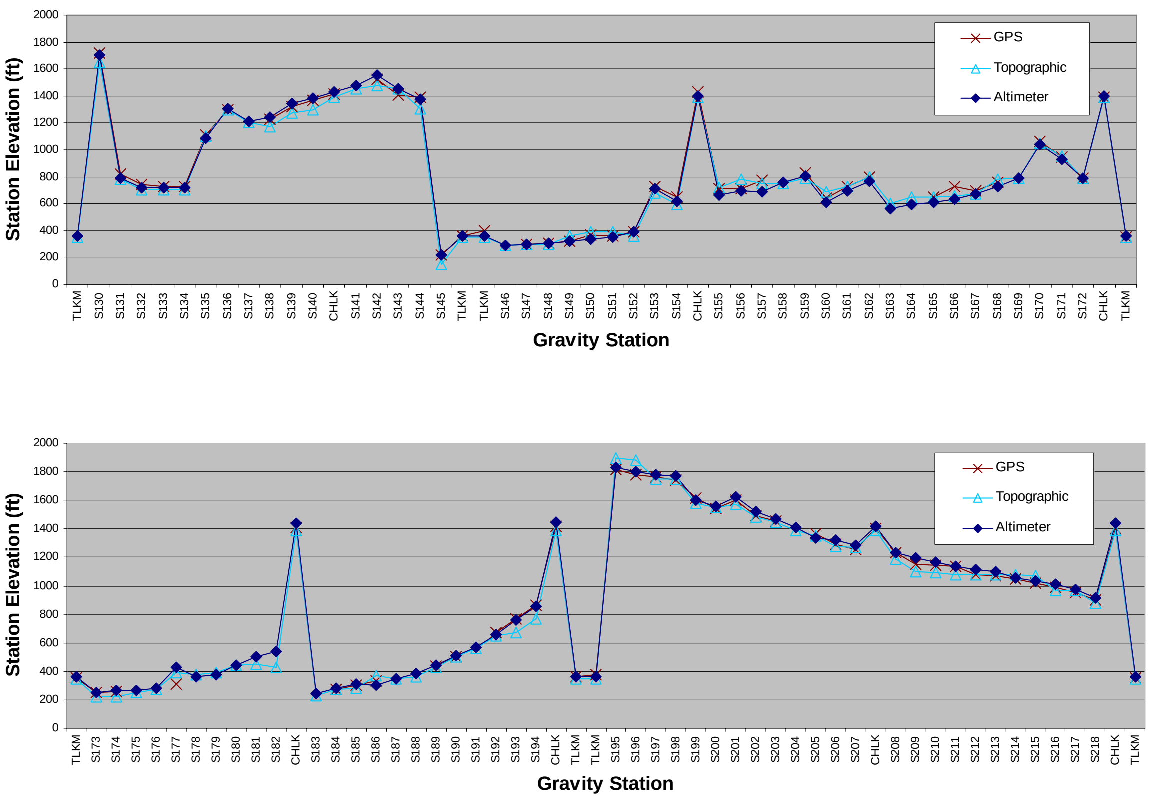

Figure 2. Graph comparing the altimetry, GPS, and topographic station elevations.

Gravity reductions were run on all of the data (including the data obtained from the USGS) using standard techniques. Corrections for the variation of gravity with latitude at each station were computed based on the Geodetic Reference System 1967 (International Association of Geodesy, 1971) using the International Gravity Standardization Net 1971 gravity datum (Morelli and others, 1974). The observed gravity values were calculated by adding the meter drift and earth-tide corrections to the meter readings converted to milligals. Free-air anomalies were calculated by subtracting the theoretical gravity from the observed gravity and adding a free-air correction. Simple Bouguer anomalies were calculated by subtracting the Bouguer correction from the free-air anomaly, calculated using a gravitational constant of 6.67×10^{-11} m^3 kg^{-1} s^{-2} and a standard density of 2.67 gm/cc. Complete Bouguer anomalies were calculated by adding the terrain correction to the simple Bouguer anomaly and isostatic anomalies were calculated by adding the isostatic correction to the complete Bouguer anomaly.

Bob Morin of the USGS computed the terrain corrections for this data by using a computer program (Plouff, 1966, 1977; Godson and Plouff, 1988) and a digital terrain model. This program calculated the gravity effects of the surrounding terrain for each station from a radial distance of 0.39 km to a distance of 166.7 km using the standard Hammer technique (Hammer, 1939), in which average elevation estimates within zones surrounding the station are used to compute the gravity effect of each zone. The station elevations used for this correction were taken from the digitized 1:63,360-scale USGS topographic maps in order to be consistent with the elevation model used for the terrain. No inner zone correction was applied due to the flat topography surrounding the stations.

Bob Morin also processed these data with an isostatic reduction program (Jachens and Roberts, 1981) to compensate for the effects of crustal roots that buoyantly support topography. The isostatic reduction assumes an Airy-Heiskanen model with a density of topography above sea level of 2.6 gm/cc and a crustal thickness at sea level of 25 km.

The principal facts for the gravity stations collected during this survey are listed in table 1. Figure 3 shows the contoured free-air anomaly values, figure 4 shows the contoured complete Bouguer anomaly values, and figure 5 shows the contoured isostatic anomaly values.

Table 1. Principal facts for the gravity stations collected during this survey. Topo represents the topographic elevation taken from 1:63,360-scale USGS topographic maps. Elev represents the station elevation used for reducing the data. FAA is the free-air anomaly, SBA is the simple Bouguer anomaly, CBA is the complete Bouguer anomaly and IA is the isostatic anomaly. Latitude and longitude are projected in NAD27.

Station	Topo		Elev		Lat (NAD27)	Lon (NAD27)	Obs Grav	FAA	SBA	CBA	IA
CHLK	1390.00	F	1410.00	F	62.43421893	-151.40674693	981926.584	-44.078	-92.167	-91.027	-20.417
S130	1650.00	F	1719.88	F	62.45262168	-151.06676121	981907.583	-35.303	-93.961	-92.561	-23.941
S131	785.00	F	818.64	F	62.42086911	-151.10736464	981954.951	-70.341	-98.262	-97.072	-30.942
S132	700.00	F	745.83	F	62.40927160	-151.13960928	981955.335	-75.942	-101.379	-100.429	-34.989
S133	700.00	F	723.82	F	62.39511993	-151.17311482	981951.711	-80.581	-105.268	-104.488	-39.968
S134	700.00	F	723.74	F	62.36399494	-151.18546654	981954.804	-75.175	-99.859	-99.169	-37.139
S135	1100.00	F	1110.32	F	62.37694732	-151.24552902	981927.572	-67.012	-104.880	-104.090	-40.340
S136	1300.00	F	1299.70	F	62.36115999	-151.25322324	981915.252	-60.341	-104.669	-104.109	-41.609
S137	1200.00	F	1210.60	F	62.34217841	-151.27890160	981917.704	-64.854	-106.143	-105.833	-44.583
S138	1175.00	F	1226.17	F	62.32976656	-151.30645244	981915.689	-64.479	-106.299	-105.999	-45.429
S139	1270.00	F	1323.94	F	62.32976656	-151.30645244	981907.497	-63.474	-108.629	-108.299	-47.729
S140	1300.00	F	1369.74	F	62.32206471	-151.38392997	981902.130	-63.958	-110.675	-110.325	-49.495
S141	1450.00	F	1474.23	F	62.30203150	-151.40850208	981895.893	-58.872	-109.152	-108.562	-48.932
S142	1475.00	F	1521.76	F	62.29237929	-151.43343835	981889.161	-60.411	-112.313	-111.813	-52.593
S143	1450.00	F	1408.48	F	62.27235073	-151.45592286	981892.348	-66.383	-114.421	-113.751	-55.631
S144	1305.00	F	1387.54	F	62.27234508	-151.47494029	981895.617	-65.083	-112.407	-111.837	-53.527
S145	150.00	F	221.49	F	62.21347057	-151.64343631	981961.924	-104.053	-111.607	-110.977	-53.647
S146	290.00	F	290.01	F	62.15017002	-151.71702598	981953.875	-100.915	-110.806	-110.416	-53.876
S147	295.00	F	295.52	F	62.14737173	-151.75657562	981952.339	-101.722	-111.801	-111.091	-53.591
S148	300.00	F	307.52	F	62.14254669	-151.77255285	981950.757	-101.814	-112.303	-111.403	-53.553
S149	360.00	F	321.59	F	62.13596050	-151.78619255	981949.617	-101.137	-112.105	-111.335	-53.235
S150	390.00	F	365.13	F	62.13851877	-151.81123113	981948.696	-98.154	-110.607	-109.697	-50.747
S151	390.00	F	357.97	F	62.13507861	-151.83965275	981948.112	-99.154	-111.363	-110.113	-50.333
S152	360.00	F	391.79	F	62.13544632	-151.87618785	981951.823	-92.290	-105.652	-103.992	-42.962
S153	680.00	F	725.36	F	62.11518099	-151.84305034	981926.759	-84.458	-109.197	-108.667	-49.157
S154	590.00	F	648.44	F	62.09663903	-151.81587020	981929.818	-87.243	-109.359	-108.849	-50.509
S155	715.00	F	707.10	F	62.06626594	-151.86655772	981932.492	-76.771	-100.888	-100.308	-40.518
S156	780.00	F	713.99	F	62.06182958	-151.88222824	981933.738	-74.543	-98.894	-98.324	-37.964
S157	750.00	F	775.07	F	62.05739415	-151.90715730	981935.518	-66.684	-93.119	-92.219	-30.949
S158	750.00	F	755.80	F	62.05456646	-151.93069628	981938.031	-65.772	-91.550	-90.310	-28.170
S159	790.00	F	830.96	F	62.05060337	-151.94500223	981937.221	-59.215	-87.556	-86.346	-23.656
S160	690.00	F	641.34	F	62.03618646	-151.93477013	981944.226	-68.962	-90.836	-89.866	-27.556
S161	730.00	F	726.39	F	62.01827345	-151.98308811	981946.947	-56.895	-81.669	-79.869	-15.539
S162	800.00	F	794.92	F	62.01349530	-152.02203294	981945.520	-51.517	-78.628	-74.118	-8.168
S163	600.00	F	561.09	F	61.96314503	-152.06990560	981955.752	-59.490	-78.626	-76.256	-7.556
S164	650.00	F	590.44	F	61.95794576	-152.10610384	981952.969	-59.120	-79.258	-76.218	-5.888
S165	650.00	F	647.05	F	61.95573624	-152.12016342	981951.727	-54.873	-76.941	-73.591	-2.641
S166	660.00	F	633.31	F	61.94937872	-152.13877316	981948.484	-58.929	-80.528	-76.558	-4.678
S167	670.00	F	692.66	F	61.95403293	-152.18652940	981949.048	-53.132	-76.756	-72.396	1.334
S168	780.00	F	759.25	F	61.95528988	-152.21908736	981947.767	-48.245	-74.140	-69.940	5.030

Table 1 (continued)

Station	Topo		Elev		Lat (NAD27)	Lon (NAD27)	Obs Grav	FAA	SBA	CBA	IA
S169	790.00	F	788.33	F	61.94662479	-152.21565530	981939.565	-53.059	-79.946	-75.356	-0.276
S170	1050.00	F	1062.38	F	61.92804658	-152.24040590	981919.031	-46.416	-82.650	-72.080	4.460
S171	950.00	F	946.47	F	61.99078254	-152.05591686	981938.238	-42.835	-75.116	-73.116	-5.526
S172	790.00	F	790.61	F	62.00531692	-152.03938853	981945.565	-51.262	-78.226	-73.806	-7.086
S173	220.00	F	254.43	F	62.29702321	-151.77379266	981989.802	-79.323	-88.000	-86.630	-22.170
S174	220.00	F	256.88	F	62.31447064	-151.79448801	981993.581	-76.617	-85.378	-83.668	-17.718
S175	250.00	F	268.48	F	62.34201711	-151.81407498	981996.598	-74.564	-83.721	-80.921	-12.881
S176	270.00	F	282.92	F	62.34848582	-151.85405913	981994.315	-75.972	-85.622	-83.432	-14.222
S177	390.00	F	428.39	F	62.37658658	-151.88153455	981991.415	-67.284	-81.895	-79.385	-7.885
S178	380.00	F	360.87	F	62.39805495	-151.91057479	981997.897	-68.753	-81.061	-78.381	-4.931
S179	390.00	F	376.68	F	62.41516118	-151.91659098	981998.167	-68.270	-81.118	-78.028	-3.318
S180	440.00	F	442.09	F	62.43262666	-151.92540345	981997.492	-64.094	-79.172	-75.832	0.198
S181	450.00	F	499.62	F	62.44531871	-151.92425765	981996.121	-60.998	-78.038	-74.368	2.532
S182	430.00	F	537.03	F	62.47060277	-151.93672530	981993.158	-62.323	-80.639	-75.929	2.921
S183	230.00	F	242.23	F	62.28231139	-151.83981262	981992.400	-76.773	-85.034	-83.534	-18.384
S184	270.00	F	272.78	F	62.30780678	-151.91325753	981995.515	-72.690	-81.993	-79.903	-11.643
S185	280.00	F	300.60	F	62.32630397	-151.96437500	981996.097	-70.871	-81.123	-78.513	-8.013
S186	370.00	F	335.51	F	62.34416288	-151.97239785	981999.434	-65.583	-77.026	-74.816	-3.226
S187	350.00	F	347.62	F	62.37043426	-152.01813289	981998.661	-67.177	-79.033	-76.343	-2.283
S188	360.00	F	383.52	F	62.38612727	-152.07033662	981997.975	-65.655	-78.736	-74.816	1.264
S189	430.00	F	432.17	F	62.39990861	-152.13245792	981995.340	-64.741	-79.481	-73.211	4.969
S190	500.00	F	499.34	F	62.41331117	-152.19679943	981993.563	-61.200	-78.230	-69.510	10.700
S191	560.00	F	566.68	F	62.43562694	-152.25906704	981993.188	-56.902	-76.229	-67.429	14.911
S192	650.00	F	671.52	F	62.45401831	-152.31163894	981993.581	-48.017	-70.920	-60.330	23.540
S193	670.00	F	765.28	F	62.47604094	-152.36368441	981990.680	-43.738	-69.838	-58.038	27.182
S194	770.00	F	861.99	F	62.50205302	-152.41874189	981986.750	-40.505	-69.904	-56.474	29.806
S195	1900.00	F	1819.13	F	62.49411742	-151.63495985	981916.363	-20.273	-82.317	-79.277	-1.067
S196	1880.00	F	1775.04	F	62.48307731	-151.60827305	981918.707	-21.255	-81.795	-78.075	-1.075
S197	1750.00	F	1764.61	F	62.47154929	-151.58209373	981919.109	-20.978	-81.161	-77.601	-1.891
S198	1750.00	F	1738.05	F	62.46225940	-151.56247207	981921.568	-20.325	-79.603	-77.073	-2.353
S199	1580.00	F	1616.79	F	62.43911310	-151.49867568	981923.973	-27.603	-82.746	-81.386	-9.416
S200	1550.00	F	1541.29	F	62.42389248	-151.46627097	981919.803	-37.742	-90.309	-89.359	-19.099
S201	1570.00	F	1601.07	F	62.43796500	-151.49185737	981923.265	-29.704	-84.310	-83.010	-11.220
S202	1480.00	F	1488.68	F	62.40566100	-151.44129172	981921.891	-39.244	-90.017	-89.227	-20.877
S203	1450.00	F	1451.99	F	62.39743510	-151.41941892	981916.007	-47.966	-97.488	-96.808	-29.418
S204	1390.00	F	1409.16	F	62.39368102	-151.38601192	981914.151	-53.571	-101.632	-101.032	-34.342
S205	1350.00	F	1365.68	F	62.38730335	-151.35931772	981914.181	-57.156	-103.734	-103.194	-37.334
S206	1280.00	F	1291.82	F	62.37687273	-151.32386196	981915.585	-61.922	-105.981	-105.501	-40.941
S207	1270.00	F	1256.84	F	62.36867161	-151.30089159	981916.265	-63.920	-106.786	-106.356	-42.736
S208	1190.00	F	1232.68	F	62.35662871	-151.29293181	981916.568	-64.991	-107.033	-106.623	-44.063
S209	1100.00	F	1153.99	F	62.32409325	-151.26568815	981922.881	-63.653	-103.011	-102.721	-42.981
S210	1090.00	F	1140.81	F	62.31095074	-151.23891688	981929.163	-57.629	-96.538	-96.308	-37.798
S211	1080.00	F	1134.88	F	62.30022854	-151.20672648	981940.864	-45.686	-84.392	-84.132	-26.702
S212	1080.00	F	1074.35	F	62.28675723	-151.19237978	981947.931	-43.305	-79.947	-79.717	-23.357
S213	1080.00	F	1072.66	F	62.27107748	-151.18690913	981948.274	-41.950	-78.534	-78.344	-23.074

Table 1 (continued)

Station	Topo		Elev		Lat (NAD27)	Lon (NAD27)	Obs Grav	FAA	SBA	CBA	IA
S214	1080.00	F	1051.23	F	62.25755016	-151.15727040	981947.900	-43.329	-79.182	-79.022	-24.902
S215	1070.00	F	1017.58	F	62.23843536	-151.12845477	981956.187	-36.776	-71.482	-71.282	-18.572
S216	970.00	F	985.49	F	62.21598456	-151.09687133	981949.157	-45.145	-78.756	-78.366	-27.236
S217	970.00	F	953.65	F	62.19109889	-151.07827869	981941.538	-53.896	-86.421	-86.121	-36.541
S218	880.00	F	903.95	F	62.16995903	-151.05426283	981940.080	-58.445	-89.275	-88.975	-40.765

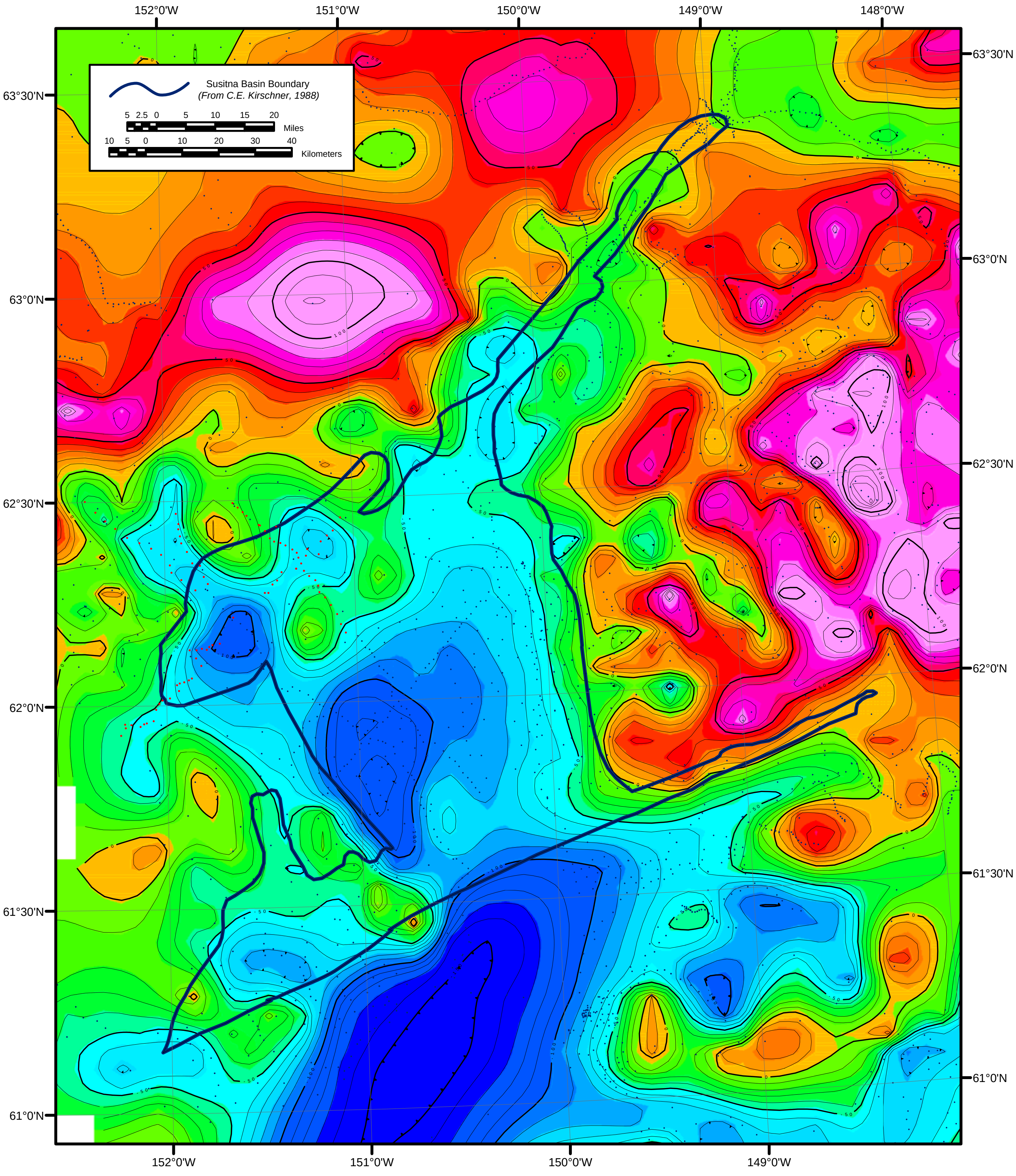

Figure 3. Free-air gravity map of the Susitna basin with a contour interval of 10 mGal.

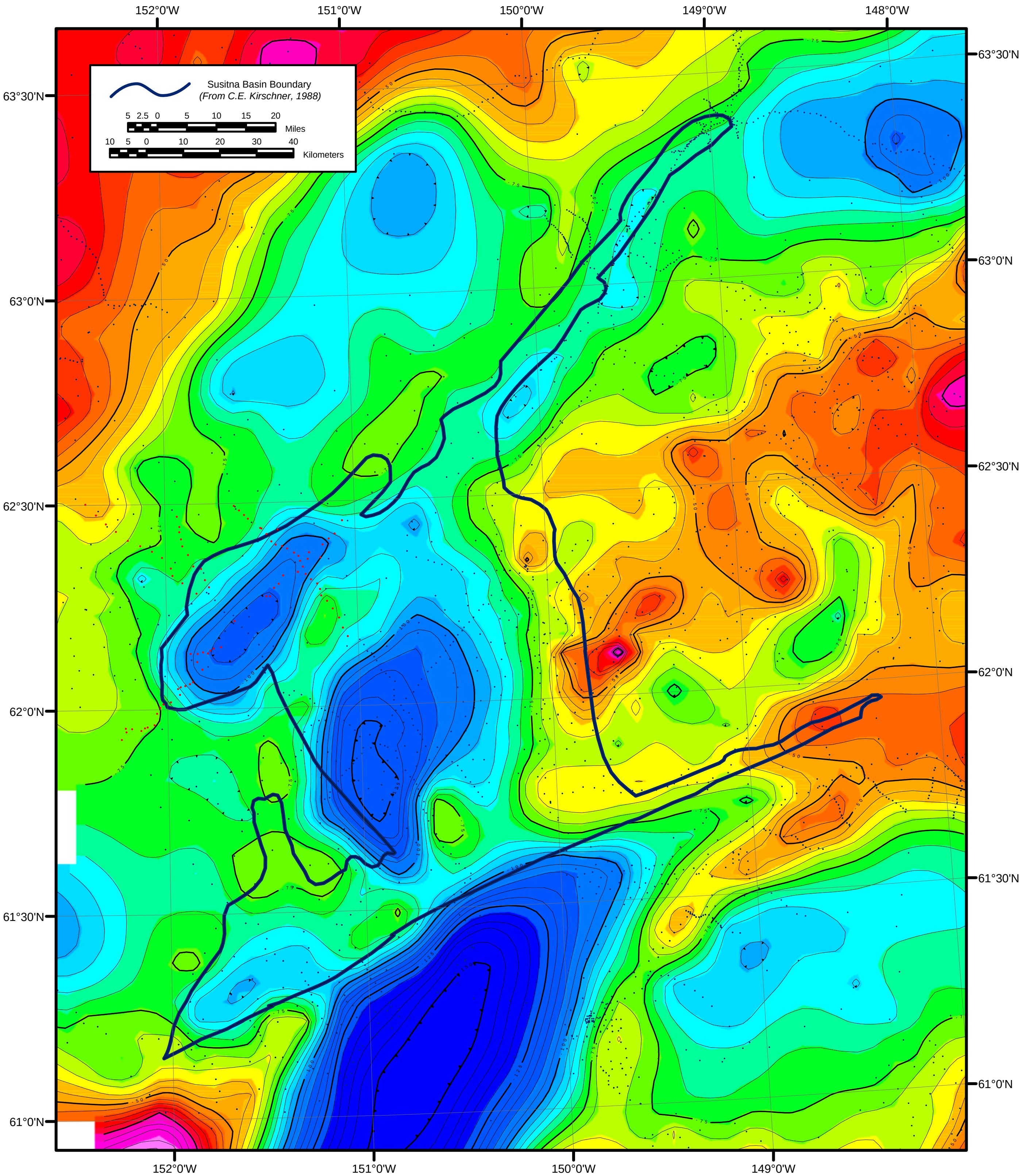

Figure 4. Complete Bouguer gravity map of the Susitna basin with a contour interval of 5 mGal.

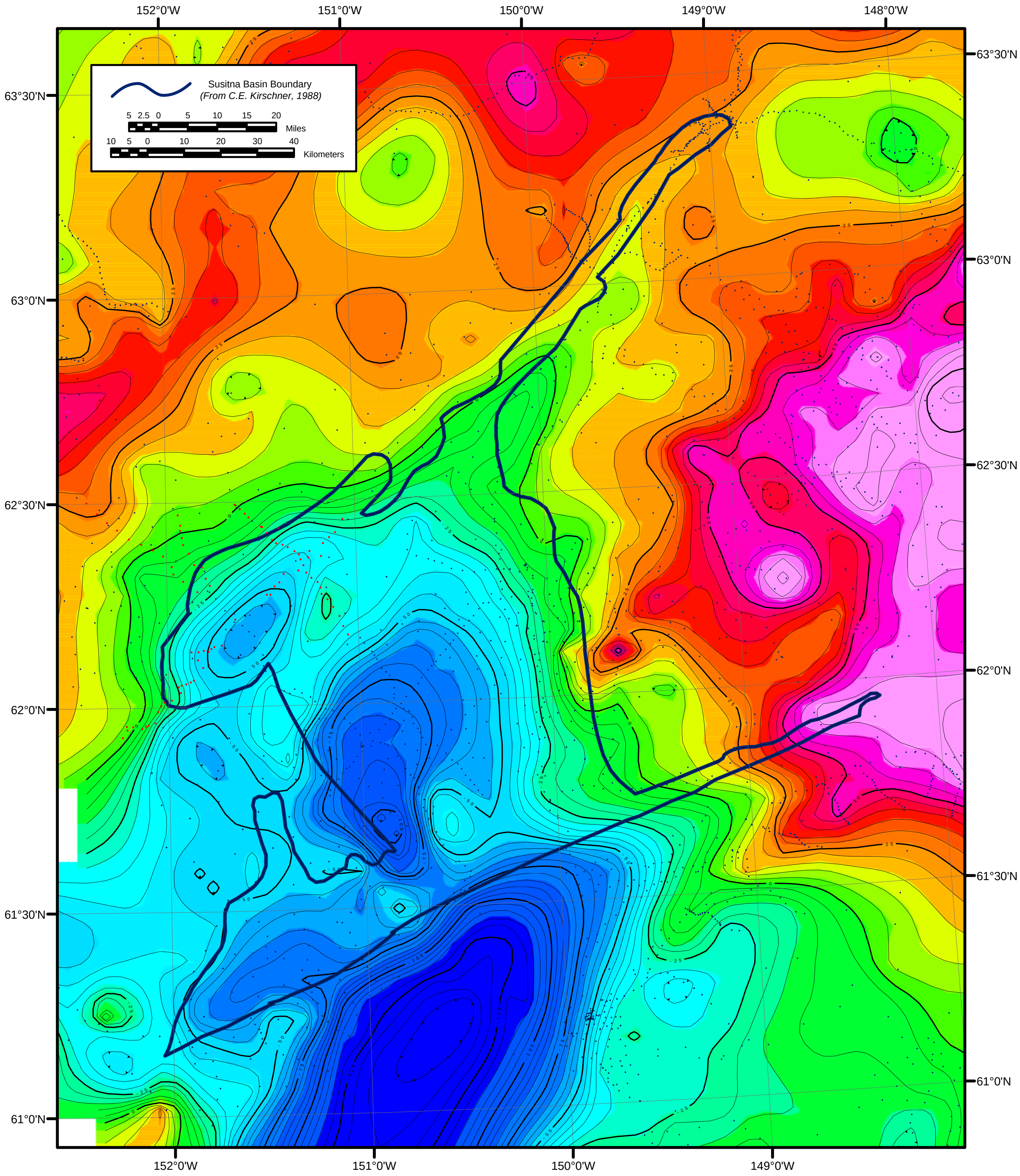

Figure 5. Isostatic gravity map of the Susitna basin with a contour interval of 5 mGal.

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