Geophysical investigation of the Denali fault and Alaska Range orogen within the aftershock zone of the October–November 2002, M = 7.9 Denali fault earthquake

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ABSTRACT

The aftershock zone of the 3 November 2002, M = 7.9 earthquake that ruptured along the right-slip Denali fault in south-central Alaska has been investigated by using gravity and magnetic, magnetotelluric, and deep-crustal, seismic reflection data as well as outcrop geology and earthquake seismology. Strong seismic reflections from within the Alaska Range orogen north of the Denali fault dip as steeply as 25°N and extend to depths as great as 20 km. These reflections outline a relict crustal architecture that in the past 20 yr has produced little seismicity. The Denali fault is nonreflective, probably because this fault dips steeply to vertical. The most intriguing finding from geophysical data is that earthquake aftershocks occurred above a rock body, with low electrical resistivity (>10 Ω·m), that is at depths below ~10 km. Aftershocks of the Denali fault earthquake have mainly occurred shallower than 10 km. A high geothermal gradient may cause the shallow seismicity. Another possibility is that the low resistivity results from fluids, which could have played a role in locating the aftershock zone by reducing rock friction within the middle and lower crust.

Keywords: earthquakes, Alaska Range, crustal structure, seismic reflection data, magnetotelluric data, potential field data.

INTRODUCTION

On 23 October 2002, a moderate (Mw = 6.7) earthquake struck near the Denali fault in south-central Alaska (Fig. 1). This event foreshadowed the November 3, Mw = 7.9, strike-slip earthquake that ruptured a 340-km-long segment of the Denali fault and adjacent faults (Eberhart-Phillips et al., 2003; Ratchkovski et al., 2003). The Denali fault earthquake was among the largest to strike within North America during the past 150 yr.

The Denali fault extends for nearly 1500 km westward along an arcuate path through south-central Alaska to near the shore of the Bering Sea (Grantz, 1966; Brogan et al., 1975; Wahrhaftig et al., 1975). This fault has long been a focus for geologic study because of the seismic hazard it poses and because the fault is interpreted to have played a prominent role in the northward translation and amalgamation of Alaskan tectonostratigraphic terranes (Csejtey et al., 1982; Nokleberg et al., 1994; Plafker et al., 1989; Ridgway et al., 2002).

In this report, outcrop geology, earthquake seismology, and a variety of geophysical data sets focus on the Denali fault within the aftershock zone of the Denali fault earthquake (Fig. 1). Geophysical data were obtained mainly along the Richardson Highway, ~100 km east of the earthquake's main shock. An integrated interpretation of geophysical and earthquake data sets allows us to separate crustal features within the Alaska Range orogen according to whether the features are seismically active. The goal is to determine which aspects of the crust might localize earthquake seismicity. Rocks having low electrical resistivity underlie the surface trace of the Denali fault, and we investigate the origin of this rock body and its potential effect on the distribution of aftershocks.

2002 EARTHQUAKE SEQUENCE

The Mw = 7.9 Denali fault earthquake (Eberhart-Phillips et al., 2003; Hreinsdottir et al., 2003; Ratchkovski et al., 2003) generated a vigorous aftershock sequence, involving thousands of events. We used a double-difference algorithm (Waldhauser and Ellsworth, 2000) to relocate aftershocks with M ≥ 2.0. Most aftershocks were shallow, clustering within the upper 10 km of the crust, but a few occurred at depths as great as 12 km (Ratchkovski et al., 2003; Fig. 2 herein). We also used the double-difference algorithm to relocate the sparse regional seismicity that occurred between 1975 and the 2002 earthquake. Like the aftershocks of the Denali fault earthquake, the regional seismicity is concentrated within the upper 10 km of the crust (Fig. 2).

REGIONAL GEOLOGY

The complicated mosaic of terranes and faults that make up the Alaska Range orogen was summarized in Ridgway et al. (2002). Near the Richardson Highway, the geology varies strongly along strike, as shown by the numerous tectonostratigraphic terranes and major faults, between the Denali and Hines Creek faults, that converge just west of the highway (Fig. 1). The Denali fault generally follows the juncture between terranes to the south that have oceanic affinity and an extensive terrane to the north having continental affinity. South of the fault, the Wrangellia terrane includes upper Paleozoic island-arc volcanic and sedimentary rocks (Nokleberg et al., 1994; Ridgway et al., 2002) that are unconformably overlain by Late Triassic basalt (Nokleberg et al., 1985, 1994). The Kahiltna terrane (Fig. 1), also south of the Denali fault, consists of Upper Jurassic and Lower Cretaceous flysch. This terrane is interpreted as one remnant of a flysch basin that once extended for several thousand kilometers along the margin of North America but has since been structurally collapsed and disrupted (Richter and Jones, 1973; Richter, 1976; Monger and Berg, 1987; Wallace et al., 1989; Rubin and Saleeby, 1991; Ridgway et al., 2002).

The Yukon-Tanana terrane, north of the Denali fault, has a continental affinity (Nokleberg et al., 1989; Dusel-Bacon, 1991; McClelland et al., 1992; Ridgway et al., 2002). During late Mesozoic time, Devonian and older sedimentary rocks as well as subordinate volcanic and plutonic rocks were in-

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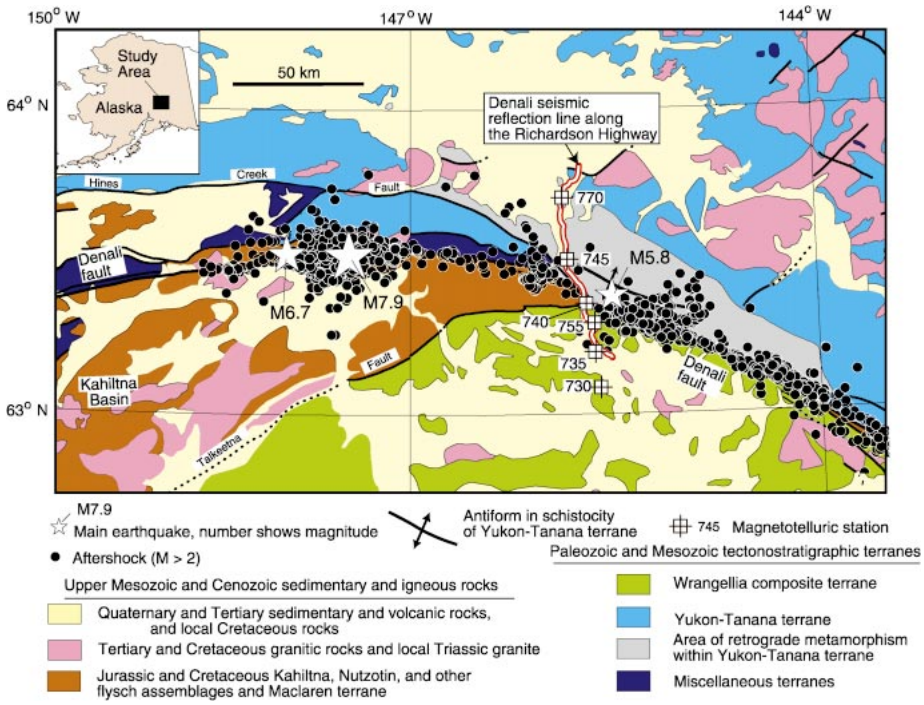

Figure 1. Geology of study area and seismicity associated with Denali fault earthquake. Geology is greatly simplified from Ridgway et al. (2002). Geophysical data shown herein were collected along Richardson Highway, ~100 km east of main shock of Denali fault earthquake.

tensely metamorphosed and ductilely deformed. During retrograde metamorphism ca. 105 Ma, a major antiform developed that follows the north side of the Denali and Hines Creek faults for >200 km (axis shown in Fig. 1).

GEOPHYSICAL DATA

Sign-bit seismic-reflection data were collected in 1986 for the U.S. Geological Survey, using a Vibroseis source and a symmetrical geophone spread 30 km long with 1024 recording channels. The seismic reflection section (Fig. 2)[1] was migrated after stack and then converted to depth.

Seismic reflection data from south of the Denali fault reveal little about the structure of the volcanic rocks in the Wrangellia terrane (Fig. 2). No fault-plane reflections reveal the locations of the Denali or Hines Creek faults, and the appearance of reflections across these faults does not change systematically to indicate any major break in the crust. However, north of these faults, strong, continuous reflections begin abruptly at ~VP (vibrator point) 2400. We group these reflections into three main reflection bands (A, B, and C in Fig. 2). Between ~4 and 7 km depth, reflection band A defines a broad synform with an axis below VP 2900. Reflection band B dips 25°N from where it begins at ~10 km below VP 2400. The strongest seismic reflections, which we call the Denali bright spot, occur between reflection bands A and B, at ~8 km below VP 2800. This bright spot is flat and very strong (inset, Fig. 2). Reflection band B flattens downward and northward into the middle crust (Fig. 2) and reflection band C diverges downward and southward from beneath band B, 20 km below VP 2800.

Magnetotelluric (MT) data show the distribution of electrical resistivity in the crust across the Denali fault (Fig. 2). During summer 2002, MT data were collected along the Richardson Highway at 6 stations, spaced 10 km to 15 km apart (Fig. 1). MT data were acquired from 3 s to 5000 s, yielding a depth of investigation of >30 km. These data were modeled by assuming two-dimensional regional structure and using the algorithm of Rodi and Mackie (2001). The strongest departures from the two-dimensional assumption were evident in electrical resistivity values derived for the Wrangellia terrane south of the Denali fault.

The electrical resistivity model outlines four main crustal bodies (Fig. 2). South of the Denali fault, within the Wrangellia terrane, high-resistivity (>2000 Ω·m) rocks make up body R1 (Fig. 2). Directly under the surface traces of the Denali and Hines Creek faults, the low-resistivity (<10 Ω·m) body R2 is nearly vertical and extends downward to the maximum modeled depth of 30 km. North of the Denali fault, the moderately resistive body R3 (~500 Ω·m) extends through much of the middle crust. The low-resistivity body R4 (<10 Ω·m) dips northward into the middle crust.

Taken together, MT and seismic reflection data show that the north boundary of the moderately resistive body R3 coincides with reflection band B (Fig. 2), and the bottom of this body approximately follows reflection band C. Furthermore, the strong reflections of the Denali bright spot are produced by rocks within the low-resistivity body R4.

South of the Denali fault, both gravity and magnetic anomaly values are relatively high and variable over the volcanic rocks that make up the Wrangellia terrane (Fig. 2). Gravity and magnetic values decrease smoothly northward across the Denali fault. Metamorphic rocks of the continental Yukon-Tanana terrane yield only subdued, potential-field anomalies.

DISCUSSION

The data ensemble presented here reveals the crustal structure that developed within the Cretaceous collision zone along the southern edge of the Yukon-Tanana terrane (e.g., Nokleberg et al., 1994) (Fig. 3). We interpret the sigmoidal shape of reflection band B and the southward divergence of bands B and C (Fig. 3) to mean that they outline part of a crustal-scale duplex structure. These bands partly outline resistivity body R3, and because this body underlies the surface antiform in Yukon-Tanana terrane rocks (antiformal axis is shown in Fig. 1), we propose that this body's emplacement caused the antiform to develop. If so, then body R3 and its associated reflections reveal features that are ca. 105 Ma, the time of retrograde metamorphism of antiformal rocks at the surface. Body R3 is not likely to include a flap of lower-crustal or upper-mantle material that was incorporated into the Alaska Range orogen because this body produces only subdued gravity and magnetic anomalies (Fig. 2). The geometry of body R3 and its associated reflections suggest southward thrust movement. In contrast to this vergence direction, northward vergence appears to have predominated south of the Denali fault because the north boundary of body R1 dips steeply south (Figs. 2 and 3). We interpret this boundary as a thrust fault that was active during terrane collision.

Our crustal-structure model for the aftershock zone and neighboring areas includes a relict zone of opposed Cretaceous thrusting that penetrates deeply (20 km) into the crust (Fig. 3). The surface trace of the Denali fault and the aftershock zone are sandwiched in the

[1]Loose insert: Figure 2. Assembled geophysical information over Denali fault, including gravity and magnetic data, seismic reflection, crustal velocity and magnetotelluric data, and earthquake seismicity.

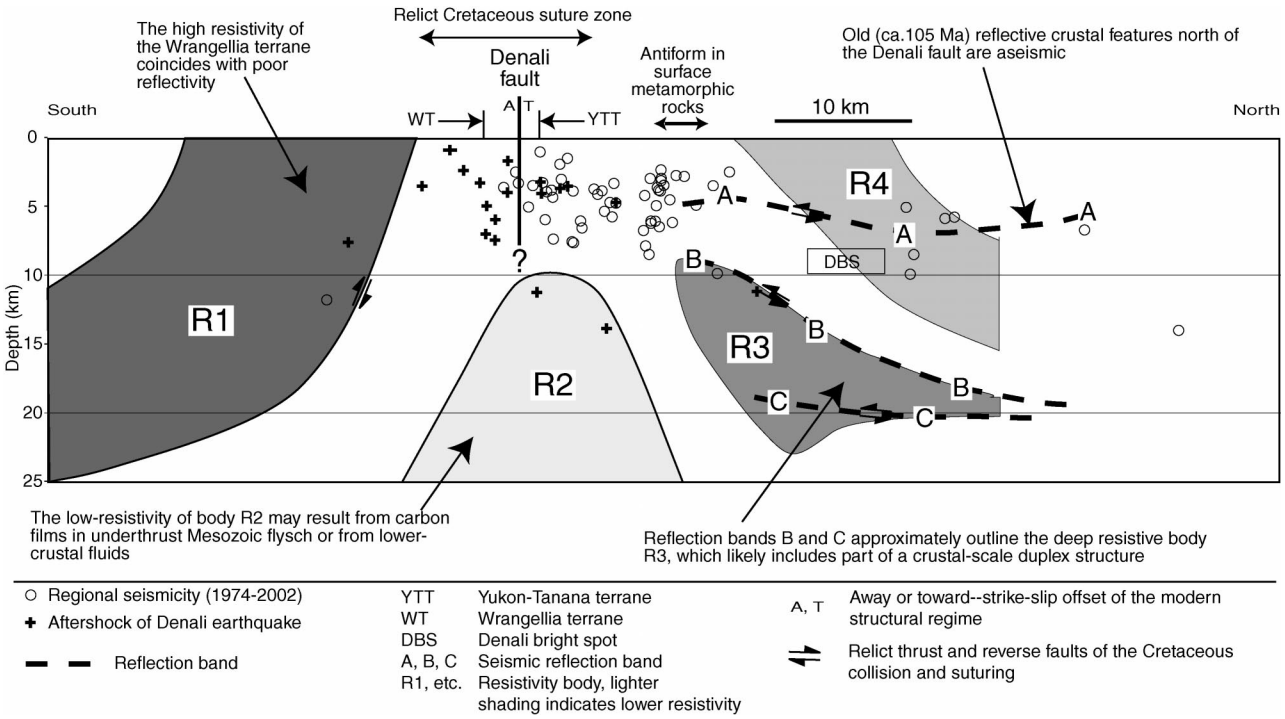

Figure 3. Tectonic model, derived from Figure 2, of Denali fault and Alaska Range orogen. Oppositely directed thrusting developed during Cretaceous terrane collision. These structures are mostly aseismic. Low-resistivity rocks in body R2 directly underlie Denali fault and probably indicate this fault's position in deep subsurface. Cause for low resistivity is unknown, but probably results from carbon films or fluids. Fluids in middle- and lower-crustal rocks could play role in localizing aftershock seismicity.

middle of this opposed-thrust zone, and both features directly overlie the low-resistivity body R2. We propose that this body indicates the Denali fault, meaning that this fault dips steeply to vertical and penetrates the Alaska Range orogen to depths of at least 30 km.

Judging from the sparse hypocenters located >10 km north of the Denali fault (Fig. 2), we propose that the highly reflective, crustal features there are relict, and are not involved in modern seismicity. Similarly, the absence of seismicity along the north boundary of body R1 indicates that it is also relict.

What accounts for the low electrical resistivity of rocks in body R2 and what effect, if any, did these rocks have on the distribution of seismicity along the Denali fault? MT surveys over other large strike-slip faults can help answer these questions. For example, the San Andreas fault near the cities of Parkfield and Hollister, California (Unsworth et al., 2000; Bedrosian et al., 2002), cuts through low-resistivity bodies down to depths of ~8–10 km. Apparently, meteoric fluids invaded the fault zone and reduced friction along the fault. These findings differ from ours because body R2 (Fig. 2) is deeper than ~10 km, which is opposite to what is found along the San Andreas fault. However, one similarity in findings about both faults is that hypocenters are outside the low-resistivity zones.

The Denali fault may be analogous tectonically to the Altyn Tagh fault of Tibet, because both faults are thought to facilitate the tectonic escape of large crustal blocks (Eberhart-Phillips et al., 2003). An MT survey over the Altyn Tagh fault revealed a low-resistivity body (10–100 Ω·m) that locally reaches the surface but mainly extends from ~4 km down to the maximum modeled depth of 8 km (Bedrosian et al., 2001). The preferred interpretation (Bedrosian et al., 2001) is that the low-resistivity body indicates carbon-rich marine sedimentary rocks that were underthrust along an old zone of weakness that pierces the lithosphere. The Altyn Tagh fault developed along this weak zone during the India-Asia collision.

Near the Denali fault, the low-resistivity body R2 is intriguing but enigmatic because of three poorly constrained variables: rock temperature, carbon content, and fluid saturation. As we discuss next, different combinations of these three variables could explain the distribution of seismicity and the low resistivity.

In general, the maximum depth of seismicity commonly is between 15 and 20 km, where rock temperature is between 350 and 400 °C (e.g., Sibson, 1982; Williams et al., 2001). Along the Denali fault, a temperature-dependent seismicity cutoff at 10 km depth would indicate a higher-than-normal geothermal gradient. No geothermal data are known from the study region. The point is that shallow seismicity along the Denali fault could result from a higher-than-normal geothermal gradient, and the depth distribution might not be influenced by the presence of body R2.

Determining the cause for the low electrical resistivity of body R2 is the main impediment to clarifying this body's role, if any, in the distribution of seismicity along the Denali fault. Low electrical resistivities below the Alaska Range could result from either carbon films or fluids. Carbon films could reduce the resistivity of metamorphic rocks in the Yukon-Tanana terrane (Mathez et al., 1995), or a thick (10 km) mass of carbon-rich flysch could underlie these mountains (Stanley, 1989; Stanley et al., 1990). In support of this contention, late Mesozoic flysch in the Kahiltna terrane ends to the northeast along the Denali fault (Fig. 1). Body R2 might represent the subsurface truncation of this flysch basin along the Denali fault. Carbon-rich flysch, however, would seem to have little bearing on the distribution of seismicity.

Crustal fluids may cause the low resistivity of body R2. The Denali bright spot occurs in the mid-crust north of the Denali fault. Smithson et al. (2000) listed possible causes for mid-crustal bright spots, including magma and acoustic tuning in rock layering, but also stressed the importance of fluids. If body R2 contains fluids, they could have an important consequence for the distribution of seismicity because high-pressure fluids can reduce fault friction (Byerlee, 1990, 1993). Fluids distributed according to the outline of body R2

might reduce friction within the middle and lower crust along the Denali fault, so that tectonic stress is borne by the relatively thin and brittle part of the crust shallower than 10 km.

CONCLUSION

Other researchers proposed that the strike-slip Denali fault developed within a suture zone that was active during Cretaceous terrane collision and suturing. We propose that the collision zone involved oppositely directed thrusting that penetrates deeply into the crust. Seismically reflective features, revealed by reflection bands A, B, and C, formed as thrust faults or as ductile shear zones within strongly metamorphosed rocks (Fig. 3), but these features appear to be seismically inactive in the present stress regime. During the Cenozoic, tectonic escape became a major mode of regional deformation, and the strike-slip Denali fault developed within the convergent suture zone. Resistivity body R2 outlines the suture zone and the Denali fault at depth. This zone has remained weak, possibly owing to entrained fluids. One possibility is that deep fluids along the Denali fault weaken the crust and localize earthquake seismicity.

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REFERENCES CITED

Beaudoin, B., Fuis, G.S., Mooney, W.D., Nokleberg, W.J., and Christensen, N.I., 1992, Thin, low-velocity crust beneath the southern Yukon-Tanana terrane, east-central Alaska: Results from Trans-Alaska crustal transect refraction/wide-angle reflection data: Journal of Geophysical Research, v. 97, p. 1921–1942.

Bedrosian, P.A., Unsworth, M.J., and Wang, F., 2001, Structure of the Altyn Tagh fault and Daxue Shan from magnetotelluric surveys: Implications for faulting associated with the rise of the Tibetan Plateau: Tectonics, v. 20, p. 474–486.

Bedrosian, P.A., Unsworth, M.J., and Egbert, G., 2002, Magnetotelluric imaging of the creeping segment of the San Andreas fault near Hollister: Geophysical Research Letters, v. 29, p. 1-1–1-4.

Brogan, G.E., Cluff, L.S., Korringa, M.K., and Slemmons, D.B., 1975, Active faults of Alaska: Tectonophysics, v. 29, p. 73–85.

Byerlee, J., 1990, Friction, overpressure and fault normal compression: Geophysical Research Letters, v. 17, p. 2109–2122.

Byerlee, J., 1993, Model for episodic flow of high-pressure water in fault zones before earthquakes: Geology, v. 21, p. 303–306.

Csejtey, B.J., Cox, D., Evarts, R.C., Stricker, G.D., and Foster, H.L., 1982, The Cenozoic Denali fault system and the Cretaceous accretionary development of southern Alaska: Journal of Geophysical Research, v. 87, p. 3741–3754.

Dusel-Bacon, C., 1991, Metamorphic history of Alaska: U.S. Geological Survey Open-File Report 91-556, 48 p.

Eberhart-Phillips, D., Haeussler, P.J., Freymueller, J.T., Frankel, A.D., Rubin, C.M., Craw, P., Ratchkovski, N.A., Anderson, G., Carver, G.A., Crone, A.J., Dawson, T.E., Fletcher, H., Hansen, R., Harp, E.L., Harris, R.A., Hill, D.P., Hreinsdottir, S., Jibson, R.W., Jones, L.N., Kayen, R., Keefer, D.K., Larsen, C.F., Moran, S.C., Personius, S.F., Plafker, G., Sherrod, B., Sieh, K., Sitar, N., and Wallace, W., 2003, The 2002 Denali fault earthquake, Alaska: A large magnitude, slip-partitioned event: Science, v. 300, p. 1113–1118.

Grantz, A., 1966, Strike-slip faults in Alaska: U.S. Geological Survey Open-File Report 82, 66 p.

Hreinsdottir, S., Freymuller, J.T., Fletcher, H.J., Larsen, C.F., and Burgmann, R., 2003, Coseismic slip distribution of the 2002 Mw7.9 Denali fault earthquake, Alaska, determined from GPS measurements: Geophysical Research Letters, v. 30, no. 13, 1670, doi: 10.1029/2003GL017447.

Mathez, E.A., Duba, A.G., Peach, C.L., Leger, A., Shankland, T.J., and Plafker, G., 1995, Electrical conductivity and carbon in metamorphic rocks of the Yukon-Tanana terrane, Alaska: Journal of Geophysical Research, v. 100, p. 10,187–10,196.

McClelland, W.C., Gehrels, G.E., Samson, S.D., and Patchett, P.J., 1992, Protolith relations of the Gravina belt and Yukon-Tanana terrane in central southeastern Alaska: Journal of Geology, v. 100, p. 107–123.

Monger, J.W.H., and Berg, H.C., 1987, Lithotectonic terrane map of western Canada and southeastern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1874b, 1 sheet, scale 1:2,500,000.

Nokleberg, W.J., Jones, D.L., and Silberling, N.J., 1985, Origin and tectonic evolution of the Maclaren and Wrangellia terranes, eastern Alaska Range, Alaska: Geological Society of America Bulletin, v. 96, p. 1251–1270.

Nokleberg, W.J., Foster, H.L., and Aleinikoff, J.N., 1989, Geology of the northern Copper River Basin, eastern Alaska Range, and southern Yukon-Tanana Basin, southern and east-central Alaska, *in* Nokleberg, W.J., and Fisher, M.A., eds., Alaskan Geological and Geophysical Transect: 1989 International Geological Congress Guidebook T104, p. 34–63.

Nokleberg, W.J., Plafker, G., and Wilson, F.H., 1994, Geology of south-central Alaska, *in* Plafker, G., and Berg, H.C., eds., The geology of Alaska: Boulder, Colorado, Geological Society of America, Geology of North America, v. G1, p. 311–366.

Plafker, G., Blome, C.D., and Siberling, N.J., 1989, Reinterpretation of lower Mesozoic rocks on the Chilkat Peninsula, Alaska, as a displaced fragment of Wrangellia: Geology, v. 17, p. 3–6.

Ratchkovski, N.A., Hansen, R.A., Stachnik, J.C., Cox, T., Fox, O., Rao, L., Clark, E., Lafevers, M., Estes, S., MacCormack, J.B., and Williams, T., 2003, Aftershock sequence of the Mw = 7.9 Denali fault, Alaska, earthquake of 3 November, 2002 from the regional seismic network data: Seismological Research Letters, v. 74, p. 743–752.

Richter, D.H., 1976, Geologic map of the Nabesna quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geological Investigations Series Map I-932, 1 sheet, scale 1:250,000.

Richter, D.H., and Jones, D.L., 1973, Structure and stratigraphy of the eastern Alaska Range, Alaska: Arctic geology, *in* Arctic geology: American Association of Petroleum Geologists Memoir 19, p. 408–420.

Ridgway, K.D., Trop, J.M., Nokleberg, W.J., Davidson, C.M., and Eastham, K.R., 2002, Mesozoic and Cenozoic tectonics of the eastern and central Alaska Range: Progressive basin development and deformation in a suture zone: Geological Society of America Bulletin, v. 114, p. 1480–1504.

Rodi, W., and Mackie, R.L., 2001, Nonlinear conjugate gradients algorithm for 2D magnetotelluric inversion: Geophysics, v. 66, p. 174–187.

Rubin, C.M., and Saleeby, J.B., 1991, The Gravina sequence: Remnants of a mid-Mesozoic oceanic arc in southern southeast Alaska: Journal of Geophysical Research, v. 96, p. 14,551–14,568.

Sibson, R.H., 1982, Fault zone models, heat flow, and the depth distribution of earthquakes in the continental crust of the United States: Seismological Society of America Bulletin, v. 72, p. 151–163.

Smithson, S.B., Wenzel, F., Ganchin, Y.V., and Morozov, I.B., 2000, Seismic results at Kola and KTB deep scientific boreholes: Velocities, reflections, fluids, and crustal composition: Tectonophysics, v. 329, p. 301–317.

Stanley, W.D., 1989, Comparison of geoelectrical/tectonic models for suture zones in the western U.S. and eastern Europe: Are black shales a possible source of high conductivities?: Physics of the Earth and Planetary Interiors, v. 53, p. 228–238.

Stanley, W.D., Labson, V.F., Nokleberg, W.J., Csejtey, B., and Fisher, M.A., 1990, The Denali fault system and Alaska Range of Alaska: Evidence for underplated Mesozoic flysch from MT surveys: Geological Society of America Bulletin, v. 102, p. 160–173.

Unsworth, M., Bedrosian, P., Eisel, M., Egbert, G., and Siripunvaraport, W., 2000, Along strike variations in the electrical structure of the San Andreas fault at Parkfield, California: Geophysical Research Letters, v. 27, p. 3021–3024.

Wahrhaftig, C., Turner, D.L., Weber, F.R., and Smith, T.E., 1975, Nature and timing of movement on the Hines Creek strand of the Denali fault system, Alaska: Geology, v. 3, p. 463–466.

Waldhauser, F., and Ellsworth, W.L., 2000, A double-difference location algorithm: Method and application to the northern Hayward fault, California: Seismological Society of America Bulletin, v. 90, p. 1353–1368.

Wallace, W.K., Hanks, C.L., and Rogers, J.F., 1989, The southern Kahiltna terrane: Implications for the tectonic evolution of southwestern Alaska: Geological Society of America Bulletin, v. 101, p. 1389–1407.

Williams, C.F., Beyer, L.A., Grubb, F.V., and Galanis, S.P., 2001, Heat flow and seismotectonics of the western Transverse Ranges: Geological Society of America Abstracts with Programs, v. 33, no. 3, p. 63.

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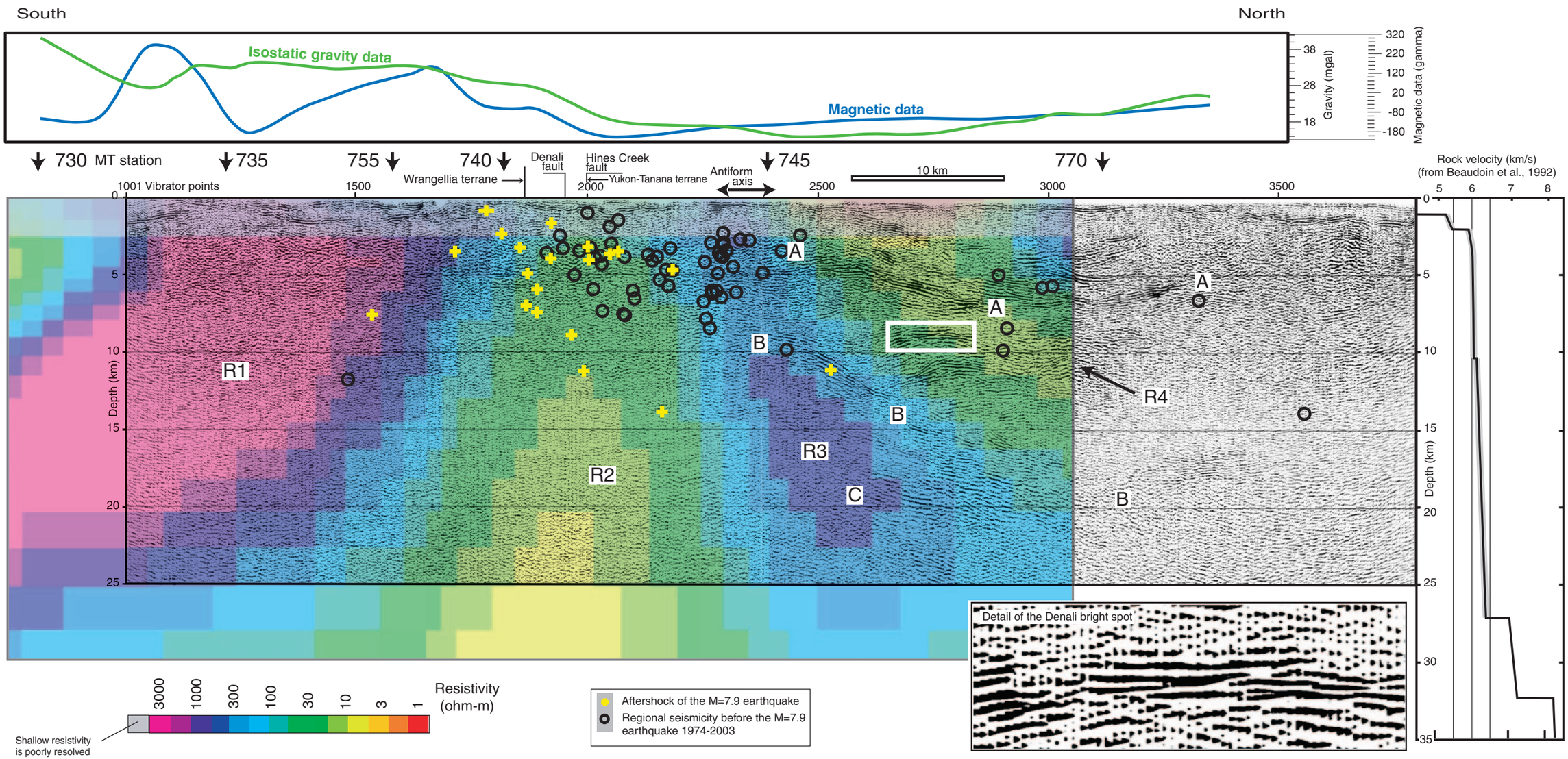

Figure 2. Assembled geophysical information over Denali fault, including gravity and magnetic, seismic reflection, crustal-velocity, and magnetotelluric data, as well as earthquake seismicity. Plane of section used in making this figure parallels Richardson Highway, which is not perpendicular to fault (Fig. 1). Hypocenters shown lie within 10 km of plane of section, and hypocenters were projected parallel to Denali fault onto section. MT is magnetotelluric.

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Figure 2
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