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TRAVEL TIMES AND B FACTORS

A.C. Chang & J.W. Lambert

Seismic Data Analysis Center

Teledyne Geotech, 314 Montgomery Street, Alexandria Virginia 22314

24 October 1978

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DF branch, amplitudes of the CD branch signals are larger than those of the DF branch signals in most of the covering range.

Discrepancies of theoretical travel times from the table based on Bolt's observations are calculated to show that tables presented here are adequate for practical use.

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ABSTRACT

Using Jordan and Anderson's earth model B1, we calculated theoretical travel times, depth allowance tables, branch interval times, and B factors for all PKP phases; the results are in tabular form. Travel times are calculated with polynomial approximations, and those coefficients are also computed.

New additions to those tables are the data for the CD branch, which are the PKiKP arrivals in the distance range of 109° to 158° . Although travel times of the CD branch fall within a few seconds of the travel times of the DF branch, amplitudes of the CD branch signals are larger than those of the DF branch signals in most of the covering range.

Discrepancies of theoretical travel times from the table based on Bolt's observations are calculated to show that tables presented here are adequate for practical use.

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INTRODUCTION

This report presents a complete set of theoretical PKP data in convenient tables, including tables of travel times of each branch at one degree intervals and at nine different source depths. Also calculated are depth allowance tables, branch interval times at various depths, and B factors for various depths.

While such tables are essential tools for data analysts and for computer programs analyzing PKP phases, only a few tables have been published. Therefore, many workers have been forced to rely upon Jeffreys' and Bullen's (J-B) seismological tables (1958), which do not give PKP travel times in convenient one-degree intervals. Later, Travis (1965) published a complete set of interpolated J-B tables for 40 different phases, both for practical use and to avoid numerous repetitive interpolations. However, the PKP travel times in the J-B tables are, according to workers, in error by approximately two seconds. Recent PKP tables, such as Hai's (1963) or Engdahl's (1968), derived from observational explosion data, are not listed at one degree intervals and they are for only one depth. Bolt (1968) published another, more widely used, table of PKP travel times at one degree intervals. This table is for surface focus and incorporates a depth allowance table to compensate for the source depth factor. However, more recent studies have indicated that the GH branch in the Bolt's table is suspicious (for example, see, Engdahl, 1968; Cleary and Haddon, 1972).

Jeffreys, H. and Bullen, K. E., 1958, Seismological Tables: British Association for the Advancement of Science Publication.

Travis, H. S., 1965, Interpolated Jeffreys and Bullen Seismological Tables, Geotech, TR-65-35, Garland, Texas.

Hai, N., 1963, Propagation des Ondes Longitudinales dans le Noyau Terrestre; Ann. Geophys., 19, 285-346.

Engdahl, E. R., 1968, Core Phases and the Earth's Core, Ph.D. Thesis, St. Louis University.

Bolt, B. A., 1968, Estimation of PKP Travel Times; Bull. Seism. Soc. Am., 58, 1305-1324.

Cleary, J. R. and R. A. W. Haddon, 1972, Seismic wave scattering near the core-mantle boundary: a new interpretation of precursors to PKP; Nature, 240, 549-551.

To fill this void a new set of PKP tables without these shortcomings is needed. We have adopted Jordan and Anderson's Earth model B1 (1974) and computed theoretical travel times and amplitudes. However, the accuracy of these values depends upon the model, a subject beyond the scope of this report. While some workers may argue that a better model exists, this model remains a widely accepted 'typical' earth model (for example, Jacobs, 1975) and travel times of PnKP phases agree with our observations at the Seismic Data Analysis Center (SDAC). A new contribution of this report is the addition of the receding CD branch, or the PKiKP phase, in the range of 109° to 158° . Although many previous studies have neglected this phase, experience shows that the signal is nonetheless commonly observable in this range. However, while this fact has been cited by Bolt (1968), Hai (1963), and Engdahl (1968), none included this branch in their tables.

Jordan, T. H., and D. L. Anderson, 1974, Earth structure from free oscillations and travel times; Geophys. J. R. Astr. Soc., 36, 411-459.

Jacobs, J. A., 1975, The Earth's Core: New York, Academic Press.

COMPUTATION OF TRAVEL TIMES

We computed theoretical travel times with Engdahl's (1968) program, CORE, and with Jordan and Anderson's model B1, (1974). CORE was modified to compute the receding CD branch in the range of 109° to 158° . These travel times are tabulated in Table I. In Table II, depth allowances, i.e., the travel time differences of PKP surface events and PKP depth events, are tabulated. This table is useful in estimating event depth when a discrepancy is found between the expected arrival time and the actual arrival time. In Table III branch interval times, or the difference in travel times between two PKP phases, are shown in various combinations and depths. This table can be used to determine or to adjust the epicenter to station distance when two PKP phases are identified in the record.

To evaluate the travel times, those computed with model B1 were compared to Bolt's PKP travel times, which were based upon observed data. However, because Bolt's tables do not have a BC branch, we compared the GH branch of the Bolt's table with the BC branch of the model B1; Figure 1 details the result. When comparing B1 to other models, we have shown the travel time difference of Bolt's travel times with the theoretical travel times computed with Herrin's (1968) mantle and Qamar's core model KOR5 (1973). The dotted lines in Figure 1 show this model's travel time difference. In this comparison, both models agree within one second with Bolt's travel times for the AB and DF branches. Although the KOR5 times seem closer to Bolt's values, there are several discrepancies: 1) Qamar's DF branch terminates at 120° while Bolt's value extends to 109° ; and 2) the GH branch terminates at 141° whereas Bolt's GH branch extends to 125° . In general, model B1 is adequate for modern use, because an error of one second is within the bounds of observational uncertainties.

Herrin, E., 1968, P-Wave Velocity Distribution in the Mantle; Bull. Seism. Soc. Am., 58, 1223-1225.

Qamar, A., 1973, Revised Velocities in the Earth's Core; Bull. Seism. Soc. Am., 63, 1073-1106.

TABLE I
TRAVEL TIMES OF PKP-AR BRANCH
(JORDAN AND ANDERSON MODEL 51)

	0	100	200	300	400	500	600	700	800
MN	0	0	0	0	0	0	0	0	0
SEC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MN	19	19	19	19	19	19	19	19	19
SEC	37.40	24.31	16.42	9.09	2.25	0.56	0.0	14.86	5.88
MN	19	19	19	19	19	19	19	19	19
SEC	40.56	28.10	20.30	12.99	5.40	0.25	0.0	17.72	9.59
MN	19	19	19	19	19	19	19	19	19
SEC	44.66	31.95	24.27	17.00	9.22	0.59	0.0	21.68	13.55
MN	19	19	19	19	19	19	19	19	19
SEC	48.82	35.91	28.30	20.99	12.04	0.88	0.0	25.70	17.64
MN	20	19	19	19	19	19	19	19	19
SEC	52.94	39.98	32.51	25.00	16.21	1.10	0.0	29.91	21.74
MN	20	19	19	19	19	19	19	19	19
SEC	57.09	43.98	36.67	29.45	20.37	1.46	0.0	34.07	25.89
MN	20	19	19	19	19	19	19	19	19
SEC	61.25	48.09	40.87	33.60	24.56	1.83	0.0	38.22	30.07
MN	20	20	20	19	19	19	19	19	19
SEC	65.41	52.26	44.95	37.90	28.78	2.20	0.0	42.37	34.25
MN	20	20	20	19	19	19	19	19	19
SEC	69.57	56.46	49.11	42.17	32.93	2.56	0.0	46.52	38.41
MN	20	20	20	19	19	19	19	19	19
SEC	73.73	60.61	53.29	46.43	37.13	2.93	0.0	50.67	42.58
MN	20	20	20	20	19	19	19	19	19
SEC	77.89	64.81	57.55	50.71	41.31	3.30	0.0	54.82	46.74
MN	20	20	20	20	19	19	19	19	19
SEC	82.05	69.01	61.75	55.00	45.50	3.67	0.0	58.97	50.91
MN	20	20	20	20	20	19	19	19	19
SEC	86.21	73.21	66.00	59.29	49.69	4.04	0.0	63.12	55.08
MN	20	20	20	20	20	20	19	19	19
SEC	90.37	77.41	70.25	63.58	53.88	4.41	0.0	67.27	59.25
MN	20	20	20	20	20	20	20	19	19
SEC	94.53	81.61	74.50	67.87	58.07	4.78	0.0	71.42	63.42
MN	20	20	20	20	20	20	20	20	19
SEC	98.69	85.81	78.70	72.16	62.26	5.15	0.0	75.57	67.59
MN	20	20	20	20	20	20	20	20	20
SEC	102.85	90.01	82.90	76.45	66.45	5.52	0.0	79.72	71.76
MN	20	20	20	20	20	20	20	20	20
SEC	107.01	94.21	87.10	80.74	70.64	5.89	0.0	83.87	75.93
MN	20	20	20	20	20	20	20	20	20
SEC	111.17	98.41	91.30	85.03	74.83	6.26	0.0	88.02	80.10
MN	20	20	20	20	20	20	20	20	20
SEC	115.33	102.61	95.50	89.32	79.02	6.63	0.0	92.17	84.27
MN	20	20	20	20	20	20	20	20	20
SEC	119.49	106.81	99.70	93.61	83.21	7.00	0.0	96.32	88.44
MN	20	20	20	20	20	20	20	20	20
SEC	123.65	111.01	103.90	97.90	87.40	7.37	0.0	100.47	92.61
MN	20	20	20	20	20	20	20	20	20
SEC	127.81	115.21	108.10	102.19	91.59	7.74	0.0	104.62	96.78
MN	20	20	20	20	20	20	20	20	20
SEC	131.97	119.41	112.30	106.48	95.78	8.11	0.0	108.77	100.95
MN	20	20	20	20	20	20	20	20	20
SEC	136.13	123.61	116.50	110.77	99.97	8.48	0.0	112.92	105.12
MN	20	20	20	20	20	20	20	20	20
SEC	140.29	127.81	120.70	115.06	104.16	8.85	0.0	117.07	109.29
MN	20	20	20	20	20	20	20	20	20
SEC	144.45	132.01	124.90	119.35	108.35	9.22	0.0	121.22	113.46
MN	20	20	20	20	20	20	20	20	20
SEC	148.61	136.21	129.10	123.64	112.54	9.59	0.0	125.37	117.63
MN	20	20	20	20	20	20	20	20	20
SEC	152.77	140.41	133.30	127.93	116.73	9.96	0.0	129.52	121.80
MN	20	20	20	20	20	20	20	20	20
SEC	156.93	144.61	137.50	132.22	120.92	10.33	0.0	133.67	125.97
MN	20	20	20	20	20	20	20	20	20
SEC	161.09	148.81	141.70	136.51	125.11	10.70	0.0	137.82	130.14
MN	20	20	20	20	20	20	20	20	20
SEC	165.25	153.01	145.90	140.80	129.30	11.07	0.0	141.97	134.31
MN	20	20	20	20	20	20	20	20	20
SEC	169.41	157.21	150.10	145.09	133.49	11.44	0.0	146.12	138.48
MN	20	20	20	20	20	20	20	20	20
SEC	173.57	161.41	154.30	149.38	137.68	11.81	0.0	150.27	142.65
MN	20	20	20	20	20	20	20	20	20
SEC	177.73	165.61	158.50	153.67	141.87	12.18	0.0	154.42	146.82
MN	20	20	20	20	20	20	20	20	20
SEC	181.89	169.81	162.70	157.96	146.06	12.55	0.0	158.57	150.99
MN	20	20	20	20	20	20	20	20	20
SEC	186.05	174.01	166.90	162.25	150.25	12.92	0.0	162.72	155.16
MN	20	20	20	20	20	20	20	20	20
SEC	190.21	178.21	171.10	166.54	154.44	13.29	0.0	166.87	159.33
MN	20	20	20	20	20	20	20	20	20
SEC	194.37	182.41	175.30	170.83	158.63	13.66	0.0	171.02	163.50
MN	20	20	20	20	20	20	20	20	20
SEC	198.53	186.61	179.50	175.12	162.82	14.03	0.0	175.17	167.67
MN	20	20	20	20	20	20	20	20	20
SEC	202.69	190.81	183.70	179.41	167.01	14.40	0.0	179.32	171.84
MN	20	20	20	20	20	20	20	20	20
SEC	206.85	195.01	187.90	183.70	171.20	14.77	0.0	183.47	176.01
MN	20	20	20	20	20	20	20	20	20
SEC	211.01	199.21	192.10	187.99	175.39	15.14	0.0	187.62	180.18
MN	20	20	20	20	20	20	20	20	20
SEC	215.17	203.41	196.30	192.28	179.58	15.51	0.0	191.77	184.35
MN	20	20	20	20	20	20	20	20	20
SEC	219.33	207.61	200.50	196.57	183.77	15.88	0.0	195.92	188.52
MN	20	20	20	20	20	20	20	20	20
SEC	223.49	211.81	204.70	200.86	187.96	16.25	0.0	200.07	192.69
MN	20	20	20	20	20	20	20	20	20
SEC	227.65	216.01	208.90	205.15	192.15	16.62	0.0	204.22	196.86
MN	20	20	20	20	20	20	20	20	20
SEC	231.81	220.21	213.10	209.44	196.34	16.99	0.0	208.37	201.03
MN	20	20	20	20	20	20	20	20	20
SEC	235.97	224.41	217.30	213.73	200.53	17.36	0.0	212.52	205.20
MN	20	20	20	20	20	20	20	20	20
SEC	240.13	228.61	221.50	218.02	204.72	17.73	0.0	216.67	209.37
MN	20	20	20	20	20	20	20	20	20
SEC	244.29	232.81	225.70	222.31	208.91	18.10	0.0	220.82	213.54
MN	20	20	20	20	20	20	20	20	20
SEC	248.45	237.01	229.90	226.60	213.10	18.47	0.0	224.97	217.71
MN	20	20	20	20	20	20	20	20	20
SEC	252.61	241.21	234.10	230.89	217.29	18.84	0.0	229.12	221.88
MN	20	20	20	20	20	20	20	20	20
SEC	256.77	245.41	238.30	235.18	221.48	19.21	0.0	233.27	226.05
MN	20	20	20	20	20	20	20	20	20
SEC	260.93	249.61	242.50	239.47	225.67	19.58	0.0	237.42	230.22
MN	20	20	20	20	20	20	20	20	20
SEC	265.09	253.81	246.70	243.76	229.86	19.95	0.0	241.57	234.39
MN	20	20	20	20	20	20	20	20	20
SEC	269.25	258.01	250.90	248.05	234.05	20.32	0.0	245.72	238.56
MN	20	20	20	20	20	20	20	20	20
SEC	273.41	262.21	255.10	252.34	238.24	20.69	0.0	249.87	242.73
MN	20	20	20	20	20	20	20	20	20
SEC	277.57	266.41	259.30	256.63	242.43	21.06	0.0	254.02	246.90
MN	20	20	20	20	20	20	20	20	20
SEC	281.73	270.61	263.50	260.92	246.62	21.43	0.0	258.17	251.07
MN	20	20	20	20	20	20	20	20	20
SEC	285.89	274.81	267.70	265.21	250.81	21.80	0.0	262.32	255.24
MN	20	20	20	20	20	20	20	20	20
SEC	290.05	279.01	271.90	269.50	255.00	22.17	0.0	266.47	259.41
MN	20	20	20	20	20	20	20	20	20
SEC	294.21	283.21	276.10	273.79	259.19	22.54	0.0	270.62	263.58
MN	20	20	20	20	20	20	20	20	20
SEC	298.37	287.41	280.30	278.08	263.38	22.91	0.0	274.77	267.75
MN	20	20	20	20	20	20	20	20	20
SEC	302.53	291.61	284.50	282.37	267.57	23.28	0.0	278.92	271.92
MN	20	20	20	20	20	20	20	20	20
SEC	306.69	295.81	288.70	286.66	271.76	23.65	0.0	283.07	276.09
MN	20	20	20	20	20	20	20	20	20
SEC	310.85	300.01	292.90	290.95	275.95	24.02	0.0	287.22	280.26
MN	20	20	20	20	20	2			

TABLE I (Continued)
TRAVEL TIMES OF PKP-BC BRANCH
(JCRDAN AND ANDERSON MODEL B1)

	0		100		200		300		400		500		600		700		800	
	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC
143	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0
144	19	37-23	19	0-36	19	0-0	19	0-0	19	0-55	18	39-50	18	0-47	18	13	18	5-74
145	19	40-46	19	24-47	19	12-58	19	1-02	18	46-79	18	36-50	18	26-67	18	14-38	18	8-85
146	19	43-40	19	27-47	19	15-49	19	4-02	18	52-75	18	42-43	18	32-58	18	17-35	18	11-63
147	19	46-25	19	30-40	19	18-29	19	6-91	18	58-38	18	45-22	18	35-12	18	20-23	18	14-38
148	19	49-00	19	33-22	19	21-03	19	9-68	18	5-62	18	48-02	18	38-81	18	26-74	18	17-10
149	19	51-71	19	35-97	19	24-02	19	12-42	19	1-10	18	50-72	18	40-43	18	31-41	18	22-15
150	19	54-35	19	38-67	19	26-72	19	15-09	19	3-76	18	53-36	18	43-43	18	34-01	18	25-33
151	19	56-92	19	41-29	19	29-33	19	17-69	19	6-34	18	55-93	18	45-99	18	36-55	18	27-85
152	19	59-42	19	43-85	19	31-88	19	20-23	19	8-87	18	58-44	18	48-90	18	39-02	18	30-30
153	19	59-42	19	46-35	19	34-77	19	22-69	19	11-32	19	5-48	18	50-26	18	41-43	18	32-69
154	20	1-86	19	48-77	19	36-77	19	25-09	19	13-71	19	3-25	18	52-55	18	43-77	18	35-01
155	20	4-22	19	51-13	19	39-12	19	27-43	19	16-03	19	5-56	18	55-78	18	46-05	18	37-27
156	20	6-52	19	53-41	19	41-39	19	29-69	19	18-28	19	7-99	18	57-96	18	48-22	18	39-41
157	20	8-76	19	55-64	19	43-61	19	31-90	19	20-48	19	9-90	18	59-00	18	50-42	18	41-61
158	20	10-93	19	57-81	19	45-76	19	34-04	0	0-0	0	0-0	0	0-0	0	0-0	0	0-0

TABLE I (Continued)
TRAVEL TIMES OF PKP-CD BRANCH
(JORDAN AND ANDERSON MODEL B1)

	0			100			200			300			400			500			600			700			800		
	MN	SPC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC	MN	SEC	SEC
109	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0	18	0	0	18	13	21	17	4	35
110	18	33	76	18	20	50	18	18	53	18	56	67	18	45	31	18	34	67	18	24	69	18	15	11	17	6	25
111	18	35	65	18	22	40	18	18	34	18	58	58	18	47	21	18	36	58	18	26	59	18	17	01	17	8	16
112	18	39	47	18	26	32	18	18	49	18	2	49	18	49	103	18	40	50	18	30	50	18	18	85	17	10	09
113	18	41	33	18	28	24	18	18	51	18	4	42	18	52	96	18	42	42	18	32	43	18	20	77	17	11	99
114	18	43	25	18	30	17	18	18	53	18	6	35	18	54	89	18	44	35	18	34	35	18	22	71	17	13	92
115	18	45	19	18	32	10	18	18	55	18	8	28	18	56	77	18	46	24	18	36	28	18	24	65	17	15	80
116	18	47	14	18	34	04	18	18	57	18	10	23	18	58	73	18	48	20	18	38	18	17	28	60	17	17	76
117	18	49	10	18	36	09	18	18	59	18	12	14	18	0	73	18	50	20	18	40	13	17	30	56	17	19	71
118	18	51	06	18	37	91	18	18	61	18	14	11	18	2	65	18	52	16	18	42	09	17	32	52	17	21	68
119	18	53	03	18	39	89	18	18	63	18	16	08	18	4	63	18	54	13	18	44	06	17	34	50	17	23	65
120	18	55	01	18	41	86	18	18	65	18	18	06	18	6	61	18	56	10	18	46	04	17	36	45	17	25	63
121	18	57	00	18	43	84	18	18	67	18	20	04	18	8	59	18	58	07	18	48	02	17	38	44	17	27	61
122	18	58	98	18	45	83	18	18	69	18	22	03	18	10	58	18	60	06	18	50	01	17	40	44	17	29	61
123	18	59	97	18	47	83	18	18	71	18	24	03	18	12	59	18	62	06	18	52	00	17	42	44	17	31	60
124	19	2	97	18	49	83	18	18	73	18	26	04	18	14	59	18	64	06	18	54	00	17	44	45	17	33	60
125	19	4	98	18	51	85	18	18	75	18	28	04	18	16	59	18	66	08	18	56	02	17	46	45	17	35	63
126	19	6	98	18	53	87	18	18	77	18	30	06	18	18	60	18	68	08	18	58	04	17	48	46	17	37	63
127	19	8	99	18	55	89	18	18	79	18	32	07	18	20	63	18	70	09	18	60	06	17	50	48	17	39	65
128	19	11	01	18	57	91	18	18	81	18	34	10	18	22	65	18	72	11	18	62	08	17	52	48	17	41	67
129	19	13	03	18	59	93	18	18	83	18	36	13	18	24	68	18	74	13	18	64	11	17	54	50	17	43	70
130	19	15	08	18	61	95	18	18	85	18	38	16	18	26	72	18	76	15	18	66	15	17	56	56	17	45	73
131	19	17	12	18	63	97	18	18	87	18	40	19	18	28	75	18	78	17	18	68	19	18	58	59	17	47	77
132	19	19	16	18	65	99	18	18	89	18	42	28	18	30	79	18	80	20	18	70	23	18	60	63	17	49	81
133	19	21	23	18	67	01	18	18	91	18	44	33	18	32	84	18	82	22	18	72	25	18	62	68	17	51	85
134	19	23	25	18	69	06	18	18	93	18	46	38	18	34	89	18	84	24	18	74	28	18	64	78	17	53	90
135	19	25	30	18	71	11	18	18	95	18	48	40	18	36	94	18	86	26	18	76	30	18	66	83	17	55	95
136	19	27	36	18	73	16	18	18	97	18	50	45	18	38	99	18	88	28	18	78	32	18	68	89	17	57	99
137	19	29	42	18	75	22	18	18	99	18	52	50	18	40	06	18	90	30	18	80	34	18	70	96	18	59	01
138	19	31	48	18	77	28	18	18	01	18	54	56	18	42	13	18	92	32	18	82	36	18	72	102	18	61	07
139	19	33	54	18	79	34	18	18	03	18	56	63	18	44	19	18	94	34	18	84	38	18	74	109	18	63	14
140	19	35	61	18	81	41	18	18	06	18	58	70	18	46	26	18	96	36	18	86	40	18	76	116	18	65	20
141	19	37	68	18	83	48	18	18	11	18	60	77	18	48	33	18	98	38	18	88	42	18	78	123	18	67	24
142	19	39	75	18	85	55	18	18	17	18	62	84	18	50	40	18	00	40	18	90	44	18	80	130	18	69	28
143	19	41	83	18	87	62	18	18	23	18	64	92	18	52	48	18	06	42	18	92	46	18	82	137	18	71	31
144	19	43	90	18	89	69	18	18	30	18	66	99	18	54	56	18	13	44	18	94	48	18	84	144	18	73	34
145	19	45	98	18	91	77	18	18	37	18	68	08	18	56	63	18	19	46	18	96	50	18	86	151	18	75	38
146	19	47	06	18	93	85	18	18	44	18	70	16	18	58	70	18	26	48	18	98	52	18	88	158	18	77	41
147	19	49	15	18	95	93	18	18	51	18	72	24	18	60	77	18	33	50	18	00	54	18	90	165	18	79	45
148	19	51	23	18	97	02	18	18	58	18	74	32	18	62	85	18	36	58	18	06	61	18	92	172	18	81	49
149	19	53	32	18	99	10	18	18	65	18	76	40	18	64	92	18	38	66	18	13	69	18	94	179	18	83	53
150	19	55	41	18	01	19	18	18	73	18	78	48	18	66	99	18	40	74	18	20	78	18	96	186	18	85	57
151	19	57	50	18	03	27	18	18	80	18	80	56	18	68	08	18	42	82	18	22	86	18	98	193	18	87	61
152	19	59	58	18	05	34	18	18	87	18	82	63	18	70	16	18	44	90	18	24	94	18	00	200	18	89	65

TABLE I (Continued)

TRAVEL TIMES OF PKP-CD BRANCH
(JORDAN AND ANDERSON MODEL R1)

	0		100		200		300		400		500		600		700		800	
	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC
153	20	0.49	19	47.36	19	35.32	19	23.59	19	12.16	19	1.65	18	51.61	18	42.07	18	33.25
154	20	2.58	19	49.45	19	37.40	19	25.68	19	14.25	19	3.74	18	53.70	18	44.16	18	35.34
155	20	4.67	19	51.54	19	39.50	19	27.77	19	16.34	19	5.83	18	55.79	18	46.25	18	37.43
156	20	6.77	19	53.63	19	41.59	19	29.86	19	18.43	19	7.92	18	57.88	18	48.34	18	39.53
157	20	8.86	19	55.72	19	43.68	19	31.95	19	20.52	19	10.01	18	59.97	18	50.43	18	41.62
158	20	10.95	19	57.82	19	45.77	19	34.04	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

TABLE I (Continued)
TRAVEL TIMES OF PKP-DF BRANCH
(JORDAN AND ANDERSON MODEL B1)

	0		100		200		300		400		500		600		700		800	
	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC	MN	SEC
109	18	0	18	0	18	0	17	0	17	0	17	0	17	0	17	13	17	4
110	18	33	18	20	18	56	17	45	17	34	17	24	17	24	17	15	17	6
111	18	35	18	22	18	58	17	47	17	36	17	26	17	26	17	16	17	8
112	18	37	18	24	18	0	17	50	17	38	17	28	17	30	17	18	17	10
113	18	39	18	26	18	2	17	52	17	40	17	30	17	32	17	20	17	11
114	18	41	18	28	18	4	17	54	17	42	17	32	17	34	17	22	17	13
115	18	43	18	30	18	6	17	56	17	44	17	34	17	36	17	24	17	15
116	18	45	18	31	18	8	17	58	17	46	17	36	17	38	17	26	17	17
117	18	46	18	33	18	9	17	59	17	47	17	37	17	39	17	28	17	19
118	18	48	18	35	18	11	17	61	17	49	17	39	17	41	17	30	17	21
119	18	50	18	37	18	13	17	63	17	51	17	41	17	43	17	32	17	23
120	18	52	18	39	18	15	17	65	17	53	17	43	17	45	17	34	17	25
121	18	54	18	41	18	17	17	67	17	55	17	45	17	47	17	36	17	27
122	18	56	18	43	18	19	17	69	17	57	17	47	17	49	17	38	17	29
123	18	58	18	45	18	21	17	71	17	59	17	49	17	51	17	40	17	31
124	18	60	18	46	18	23	17	73	17	61	17	51	17	53	17	42	17	33
125	18	62	18	48	18	25	17	75	17	63	17	53	17	55	17	44	17	35
126	18	64	18	50	18	26	17	77	17	65	17	55	17	57	17	46	17	37
127	18	66	18	52	18	28	17	79	17	67	17	57	17	59	17	48	17	39
128	18	68	18	54	18	30	17	81	17	69	17	59	17	61	17	50	17	41
129	18	70	18	56	18	32	17	83	17	71	17	61	17	63	17	52	17	43
130	18	72	18	58	18	34	17	85	17	73	17	63	17	65	17	54	17	45
131	18	74	18	59	18	36	17	87	17	75	17	65	17	67	17	56	17	47
132	18	76	18	61	18	38	17	89	17	77	17	67	17	69	17	58	17	49
133	18	78	18	63	18	40	17	91	17	79	17	69	17	71	17	60	17	51
134	18	80	18	65	18	42	17	93	17	81	17	71	17	73	17	62	17	53
135	18	82	18	67	18	44	17	95	17	83	17	73	17	75	17	64	17	55
136	18	84	18	69	18	46	17	97	17	85	17	75	17	77	17	66	17	57
137	18	86	18	71	18	48	17	99	17	87	17	77	17	79	17	68	17	59
138	18	88	18	73	18	50	17	101	17	89	17	79	17	81	17	70	17	61
139	18	90	18	75	18	52	17	103	17	91	17	81	17	83	17	72	17	63
140	18	92	18	77	18	54	17	105	17	93	17	83	17	85	17	74	17	65
141	18	94	18	79	18	56	17	107	17	95	17	85	17	87	17	76	17	67
142	18	96	18	81	18	58	17	109	17	97	17	87	17	89	17	78	17	69
143	18	98	18	83	18	60	17	111	17	99	17	89	17	91	17	80	17	71
144	18	100	18	85	18	62	17	113	17	101	17	91	17	93	17	82	17	73
145	18	102	18	87	18	64	17	115	17	103	17	93	17	95	17	84	17	75
146	18	104	18	89	18	66	17	117	17	105	17	95	17	97	17	86	17	77
147	18	106	18	91	18	68	17	119	17	107	17	97	17	99	17	88	17	79
148	18	108	18	93	18	70	17	121	17	109	17	99	17	101	17	90	17	81
149	18	110	18	95	18	72	17	123	17	111	17	101	17	103	17	92	17	83
150	18	112	18	97	18	74	17	125	17	113	17	103	17	105	17	94	17	85

TABLE I (Continued)
TRAVEL TIMES OF PKP-DF BRANCH
(JORDAN AND ANDERSON MODEL P1)

	0	100	200	300	400	500	600	700	800
151	19	19	19	19	18	18	18	18	18
152	19	19	19	19	18	18	18	18	18
153	19	19	19	19	18	18	18	18	18
154	19	19	19	19	18	18	18	18	18
155	19	19	19	19	18	18	18	18	18
156	19	19	19	19	18	18	18	18	18
157	19	19	19	19	18	18	18	18	18
158	19	19	19	19	18	18	18	18	18
159	19	19	19	19	18	18	18	18	18
160	19	19	19	19	18	18	18	18	18
161	19	19	19	19	18	18	18	18	18
162	19	19	19	19	18	18	18	18	18
163	19	19	19	19	18	18	18	18	18
164	19	19	19	19	18	18	18	18	18
165	19	19	19	19	18	18	18	18	18
166	19	19	19	19	18	18	18	18	18
167	19	19	19	19	18	18	18	18	18
168	19	19	19	19	18	18	18	18	18
169	19	19	19	19	18	18	18	18	18
170	19	19	19	19	18	18	18	18	18
171	19	19	19	19	18	18	18	18	18
172	19	19	19	19	18	18	18	18	18
173	19	19	19	19	18	18	18	18	18
174	19	19	19	19	18	18	18	18	18
175	19	19	19	19	18	18	18	18	18
176	19	19	19	19	18	18	18	18	18
177	19	19	19	19	18	18	18	18	18
178	19	19	19	19	18	18	18	18	18
179	19	19	19	19	18	18	18	18	18
180	19	19	19	19	18	18	18	18	18
	47.67	34.48	23.36	10.55	59.04	48.44	38.30	28.65	19.71
	49.16	35.99	25.38	12.06	0.54	49.94	39.79	30.14	21.64
	50.67	37.47	26.88	13.53	2.01	51.40	42.25	31.59	22.64
	52.18	38.91	28.34	14.97	3.44	52.83	44.67	33.00	24.05
	53.69	40.38	29.81	16.43	4.83	54.26	47.05	34.38	25.42
	55.20	41.80	30.30	17.90	6.18	55.67	49.39	35.71	26.75
	56.71	43.28	31.73	19.36	7.49	57.08	51.70	37.01	28.03
	58.22	44.71	33.16	20.80	8.76	58.43	54.00	38.26	29.28
	59.73	46.19	34.55	22.23	9.97	59.85	56.26	39.46	30.47
	61.24	47.61	35.93	23.65	11.14	61.26	58.51	40.60	31.69
	62.75	49.08	37.33	25.07	12.25	62.67	60.74	41.75	32.74
	64.26	50.50	38.73	26.48	13.32	64.08	62.94	42.87	33.74
	65.77	51.92	40.13	27.89	14.34	65.49	65.11	44.00	34.69
	67.28	53.34	41.55	29.29	15.30	66.90	67.27	45.16	35.59
	68.79	54.76	42.97	30.69	16.22	68.31	69.40	46.26	36.43
	70.30	56.18	44.39	32.08	17.08	69.72	71.50	47.20	37.22
	71.81	57.59	45.80	33.47	17.89	71.13	73.57	48.08	38.06
	73.32	59.01	47.21	34.85	18.65	72.54	75.62	48.93	38.94
	74.83	60.42	48.63	36.23	19.38	73.96	77.65	49.78	39.82
	76.34	61.84	50.04	37.61	19.98	75.38	79.66	50.61	40.63
	77.85	63.25	51.45	39.00	20.56	76.80	81.65	51.43	41.34
	79.36	64.67	52.87	40.37	21.08	78.22	83.62	52.24	42.18
	80.87	66.08	54.29	41.74	21.54	79.64	85.58	53.04	42.99
	82.38	67.50	55.71	43.11	21.94	81.06	87.53	53.84	43.78
	83.89	68.91	57.13	44.48	22.28	82.48	89.47	54.64	44.51
	85.40	70.33	58.55	45.85	22.55	83.90	91.40	55.44	45.23
	86.91	71.74	59.97	47.22	22.77	85.32	93.32	56.24	45.99
	88.42	73.16	61.39	48.59	22.93	86.74	95.24	57.04	46.73
	89.93	74.57	62.81	49.96	23.02	88.16	97.16	57.84	47.43
	91.44	75.99	64.23	51.33	23.07	89.58	99.07	58.64	48.13
	92.95	77.40	65.65	52.70	23.08	91.00	100.97	59.44	48.83
	94.46	78.82	67.07	54.07	23.08	92.42	102.87	60.24	49.53
	95.97	80.23	68.49	55.44	23.08	93.84	104.77	61.04	50.23
	97.48	81.65	69.91	56.81	23.08	95.26	106.67	61.84	50.93
	98.99	83.06	71.33	58.18	23.08	96.68	108.57	62.64	51.63
	100.50	84.48	72.75	59.55	23.08	98.10	110.47	63.44	52.33
	102.01	85.89	74.17	60.92	23.08	99.52	112.37	64.24	53.03
	103.52	87.31	75.59	62.29	23.08	100.94	114.27	65.04	53.73
	105.03	88.72	77.01	63.66	23.08	102.36	116.17	65.84	54.43
	106.54	90.14	78.43	65.03	23.08	103.78	118.07	66.64	55.13
	108.05	91.55	79.85	66.40	23.08	105.20	119.97	67.44	55.83
	109.56	92.97	81.27	67.77	23.08	106.62	121.87	68.24	56.53
	111.07	94.38	82.69	69.14	23.08	108.04	123.77	69.04	57.23
	112.58	95.80	84.11	70.51	23.08	109.46	125.67	69.84	57.93
	114.09	97.21	85.53	71.88	23.08	110.88	127.57	70.64	58.63
	115.60	98.63	86.95	73.25	23.08	112.30	129.47	71.44	59.33
	117.11	100.04	88.37	74.62	23.08	113.72	131.37	72.24	60.03
	118.62	101.46	89.79	76.00	23.08	115.14	133.27	73.04	60.73
	120.13	102.87	91.21	77.37	23.08	116.56	135.17	73.84	61.43
	121.64	104.29	92.63	78.74	23.08	117.98	137.07	74.64	62.13
	123.15	105.70	94.05	80.11	23.08	119.40	138.97	75.44	62.83
	124.66	107.12	95.47	81.48	23.08	120.82	140.87	76.24	63.53
	126.17	108.53	96.89	82.85	23.08	122.24	142.77	77.04	64.23
	127.68	109.95	98.31	84.22	23.08	123.66	144.67	77.84	64.93
	129.19	111.36	99.73	85.59	23.08	125.08	146.57	78.64	65.63
	130.70	112.78	101.15	86.96	23.08	126.50	148.47	79.44	66.33
	132.21	114.19	102.57	88.33	23.08	127.92	150.37	80.24	67.03
	133.72	115.61	103.99	89.70	23.08	129.34	152.27	81.04	67.73
	135.23	117.02	105.41	91.07	23.08	130.76	154.17	81.84	68.43
	136.74	118.44	106.83	92.44	23.08	132.18	156.07	82.64	69.13
	138.25	119.85	108.25	93.81	23.08	133.60	157.97	83.44	69.83
	139.76	121.27	109.67	95.18	23.08	135.02	159.87	84.24	70.53
	141.27	122.68	111.09	96.55	23.08	136.44	161.77	85.04	71.23
	142.78	124.10	112.51	97.92	23.08	137.86	163.67	85.84	71.93
	144.29	125.51	113.93	99.29	23.08	139.28	165.57	86.64	72.63
	145.80	126.93	115.35	100.66	23.08	140.70	167.47	87.44	73.33
	147.31	128.34	116.77	102.03	23.08	142.12	169.37	88.24	74.03
	148.82	129.76	118.19	103.40	23.08	143.54	171.27	89.04	74.73
	150.33	131.17	119.61	104.77	23.08	144.96	173.17	89.84	75.43
	151.84	132.59	121.03	106.14	23.08	146.38	175.07	90.64	76.13
	153.35	134.00	122.45	107.51	23.08	147.80	176.97	91.44	76.83
	154.86	135.42	123.87	108.88	23.08	149.22	178.87	92.24	77.53
	156.37	136.83	125.29	110.25	23.08	150.64	180.77	93.04	78.23
	157.88	138.25	126.71	111.62	23.08	152.06	182.67	93.84	78.93
	159.39	139.66	128.13	112.99	23.08	153.48	184.57	94.64	79.63
	160.90	141.08	129.55	114.36	23.08	154.90	186.47	95.44	80.33
	162.41	142.49	130.97	115.73	23.08	156.32	188.37	96.24	81.03
	163.92	143.91	132.39	117.10	23.08	157.74	190.27	97.04	81.73
	165.43	145.32	133.81	118.47	23.08	159.16	192.17	97.84	82.43
	166.94	146.74	135.23	119.84	23.08	160.58	194.07	98.64	83.13
	168.45	148.15	136.65	121.21	23.08	162.00	195.97	99.44	83.83
	169.96	149.57	138.07	122.58	23.08	163.42	197.87	100.24	84.53
	171.47	150.98	139.49	123.95	23.08	164.84	199.77	101.04	85.23
	172.98	152.40	140.91	125.32	23.08	166.26	201.67	101.84	85.93
	174.49	153.81	142.33	126.69	23.08	167.68	203.57	102.64	86.63
	176.00	155.23	143.75	128.06	23.08	169.10	205.47	103.44	87.33
	177.51	156.64	145.17	129.43	23.08	170.52	207.37	104.24	88.03
	179.02	158.06	146.59	130.80	23.08	171.94	209.27	105.04	88.73
	180.53	159.47	148.01	132.17	23.08	173.36	211.17	105.84	89.43

TABLE II
DEPTH ALLOWANCES FOR PKP-AB BRANCH
(JORDAN AND ANDERSON MODEL B1)
(TO BE SUBTRACTED FROM 0 DEPTH TRAVEL TIMES)

DEPTH	100	200	300	400	500	600	700	800
145	12.85	24.58	35.95	46.99	57.03	66.33	75.52	83.65
146	12.82	24.50	35.83	46.83	56.84	66.15	75.24	83.34
147	12.79	24.43	35.74	46.72	56.69	66.01	75.04	83.10
148	12.76	24.39	35.67	46.63	56.58	65.91	74.88	82.77
149	12.75	24.36	35.62	46.56	56.50	65.82	74.75	82.55
150	12.73	24.34	35.59	46.51	56.46	65.74	74.65	82.53
151	12.71	24.31	35.55	46.45	56.42	65.66	74.55	82.33
152	12.70	24.29	35.51	46.40	56.36	65.59	74.46	82.35
153	12.68	24.27	35.48	46.36	56.32	65.54	74.38	82.21
154	12.67	24.25	35.46	46.33	56.29	65.49	74.31	82.17
155	12.66	24.23	35.43	46.29	56.24	65.44	74.24	82.10
156	12.65	24.22	35.40	46.26	56.21	65.40	74.18	82.04
157	12.64	24.21	35.37	46.21	56.18	65.35	74.14	81.99
158	12.63	24.19	35.36	46.19	56.17	65.33	74.09	81.94
159	12.62	24.17	35.33	46.15	56.13	65.28	74.00	81.86
160	12.61	24.16	35.32	46.14	56.12	65.26	73.95	81.82
161	12.60	24.15	35.31	46.12	56.11	65.24	73.93	81.79
162	12.59	24.14	35.30	46.11	56.10	65.22	73.91	81.77
163	12.58	24.13	35.29	46.10	56.09	65.20	73.89	81.75
164	12.57	24.12	35.28	46.09	56.08	65.18	73.88	81.74
165	12.56	24.11	35.27	46.08	56.07	65.17	73.86	81.72
166	12.55	24.10	35.26	46.07	56.06	65.15	73.84	81.69
167	12.54	24.09	35.25	46.06	56.05	65.13	73.82	81.67
168	12.53	24.08	35.24	46.05	56.04	65.12	73.81	81.66
169	12.52	24.07	35.23	46.04	56.03	65.10	73.80	81.65
170	12.51	24.06	35.22	46.03	56.02	65.08	73.79	81.63
171	12.50	24.05	35.21	46.02	56.01	65.06	73.77	81.61
172	12.49	24.04	35.20	46.01	56.00	65.04	73.75	81.60
173	12.48	24.03	35.19	46.00	55.99	65.03	73.74	81.59
174	12.47	24.02	35.18	45.99	55.98	65.02	73.73	81.58
175	12.46	24.01	35.17	45.98	55.97	65.01	73.72	81.57
176	12.45	24.00	35.16	45.97	55.96	65.00	73.71	81.56
177	12.44	23.99	35.15	45.96	55.95	65.00	73.70	81.55

TABLE II (Continued)

 DEPTH ALLOWANCES FOR PKP-BC BRANCH
 (JORDAN AND ANDERSON MODEL B1)

(TO BE SUBTRACTED FROM 0 DEPTH TRAVEL TIMES)

DELTA	100	200	300	400	500	600	700	800
145	12.87	24.70	36.21	47.44	57.73	67.56	76.88	85.45
146	12.99	24.88	36.44	47.71	58.03	67.88	77.23	85.83
147	13.00	24.91	36.49	47.78	58.14	68.02	77.39	86.02
148	13.03	24.96	36.57	47.87	58.23	68.13	77.51	86.15
149	13.04	24.97	36.58	47.90	58.28	68.19	77.59	86.25
150	13.06	24.99	36.62	47.95	58.35	68.28	77.70	86.38
151	13.07	25.02	36.66	48.01	58.42	68.36	77.80	86.50
152	13.07	25.04	36.69	48.05	58.48	68.44	77.90	86.62
153	13.09	25.06	36.73	48.10	58.54	68.52	77.99	86.73
154	13.09	25.09	36.77	48.15	58.61	68.60	78.09	86.85
155	13.09	25.10	36.79	48.19	58.66	68.67	78.17	86.95
156	13.11	25.13	36.83	48.24	58.72	68.74	78.26	87.05
157	13.12	25.15	36.86	48.28	58.77	68.80	78.34	87.15
158	13.12	25.17	36.89	48.30	58.80	68.80	78.34	87.15

TABLE II (Continued)

 DEPTH ALLOWANCES FOR PKP-CD BRANCH
 (JORDAN AND ANDERSON MODEL B1)

(TO BE SUBTRACTED FROM 0 DEPTH TRAVEL TIMES)

DELTA	100	200	300	400	500	600	700	800
110	13.16	25.23	36.98	48.45	58.99	69.07	78.65	87.51
111	13.15	25.22	36.98	48.44	58.98	69.06	78.64	87.49
112	13.16	25.23	36.98	48.44	58.98	69.06	78.63	87.49
113	13.15	25.23	36.98	48.44	58.97	69.04	78.62	87.48
114	13.15	25.22	36.97	48.43	58.97	69.04	78.62	87.47
115	13.15	25.22	36.97	48.43	58.97	69.04	78.61	87.46
116	13.15	25.22	36.97	48.42	58.95	69.02	78.60	87.45
117	13.15	25.21	36.96	48.42	58.95	69.01	78.59	87.43
118	13.15	25.21	36.96	48.41	58.94	69.01	78.58	87.43
119	13.15	25.21	36.96	48.41	58.94	69.01	78.58	87.42
120	13.15	25.21	36.95	48.41	58.93	69.00	78.56	87.41
121	13.14	25.21	36.95	48.40	58.93	68.99	78.56	87.40
122	13.15	25.21	36.95	48.40	58.93	68.99	78.56	87.40
123	13.15	25.21	36.95	48.40	58.92	68.98	78.55	87.38
124	13.15	25.21	36.95	48.39	58.92	68.98	78.54	87.38
125	13.14	25.20	36.94	48.39	58.91	68.97	78.53	87.37
126	13.14	25.20	36.94	48.38	58.91	68.96	78.52	87.36
127	13.14	25.20	36.94	48.38	58.90	68.96	78.52	87.35
128	13.14	25.20	36.93	48.38	58.90	68.95	78.51	87.34
129	13.14	25.20	36.94	48.38	58.90	68.95	78.51	87.34
130	13.14	25.20	36.93	48.38	58.90	68.95	78.51	87.33
131	13.14	25.19	36.92	48.37	58.88	68.94	78.49	87.32
132	13.13	25.19	36.92	48.36	58.88	68.93	78.49	87.31
133	13.14	25.19	36.93	48.37	58.88	68.93	78.49	87.31
134	13.14	25.19	36.92	48.37	58.89	68.93	78.48	87.31
135	13.14	25.19	36.92	48.36	58.87	68.92	78.47	87.30
136	13.14	25.19	36.92	48.36	58.87	68.92	78.47	87.30
137	13.14	25.19	36.92	48.36	58.87	68.92	78.47	87.29
138	13.14	25.19	36.92	48.36	58.87	68.92	78.47	87.29
139	13.14	25.19	36.92	48.36	58.87	68.92	78.46	87.28
140	13.14	25.19	36.92	48.35	58.86	68.91	78.46	87.28
141	13.13	25.18	36.91	48.35	58.86	68.90	78.45	87.27
142	13.13	25.18	36.91	48.35	58.86	68.90	78.45	87.27
143	13.13	25.18	36.91	48.35	58.86	68.90	78.45	87.27
144	13.13	25.18	36.91	48.34	58.85	68.90	78.44	87.26
145	13.14	25.19	36.91	48.35	58.86	68.90	78.45	87.26
146	13.13	25.18	36.91	48.34	58.85	68.89	78.44	87.25
147	13.13	25.18	36.90	48.34	58.85	68.89	78.43	87.25
148	13.13	25.18	36.90	48.34	58.84	68.89	78.43	87.25
149	13.13	25.18	36.91	48.34	58.85	68.89	78.43	87.25
150	13.13	25.18	36.90	48.34	58.84	68.89	78.43	87.24
151	13.13	25.18	36.91	48.34	58.85	68.89	78.43	87.25
152	13.14	25.18	36.91	48.34	58.85	68.89	78.43	87.25
153	13.13	25.17	36.90	48.33	58.84	68.88	78.42	87.24
154	13.13	25.18	36.90	48.33	58.84	68.88	78.42	87.24
155	13.13	25.17	36.90	48.33	58.84	68.88	78.42	87.24
156	13.14	25.18	36.91	48.34	58.85	68.89	78.43	87.24
157	13.14	25.18	36.91	48.34	58.85	68.89	78.43	87.24
158	13.13	25.18	36.91	0.0	0.0	0.0	0.0	0.0

TABLE II (Continued)

DEPTH ALLOWANCES FOR PKP-DF BRANCH
(JORDAN AND ANDERSON MODEL B1)

(TO BE SUBTRACTED FROM 0 DEPTH TRAVEL TIMES)

DELTA	100	200	300	400	500	600	700	800
110	13.15	25.23	36.98	48.45	58.99	69.07	78.66	87.52
111	13.16	25.23	36.99	48.45	58.99	69.07	78.66	87.52
112	13.16	25.23	36.99	48.45	58.99	69.07	78.66	87.52
113	13.16	25.23	36.99	48.45	59.00	69.07	78.66	87.52
114	13.16	25.23	36.99	48.45	59.00	69.08	78.66	87.52
115	13.15	25.23	36.98	48.45	58.99	69.07	78.65	87.52
116	13.15	25.23	36.98	48.45	58.99	69.07	78.66	87.52
117	13.16	25.23	36.99	48.45	59.00	69.08	78.66	87.52
118	13.15	25.23	36.98	48.45	58.99	69.07	78.66	87.52
119	13.16	25.24	36.99	48.46	59.00	69.08	78.67	87.53
120	13.16	25.23	36.99	48.46	59.00	69.08	78.67	87.53
121	13.16	25.23	36.99	48.45	59.00	69.08	78.67	87.53
122	13.16	25.23	36.99	48.46	59.00	69.08	78.67	87.54
123	13.16	25.24	37.00	48.46	59.01	69.09	78.68	87.54
124	13.16	25.24	37.00	48.46	59.01	69.09	78.68	87.55
125	13.16	25.24	37.00	48.46	59.01	69.09	78.68	87.55
126	13.16	25.24	37.00	48.47	59.02	69.10	78.69	87.56
127	13.16	25.24	37.00	48.47	59.01	69.10	78.69	87.56
128	13.16	25.24	37.00	48.47	59.02	69.11	78.70	87.57
129	13.16	25.24	37.00	48.47	59.02	69.11	78.70	87.57
130	13.16	25.24	37.00	48.48	59.02	69.11	78.71	87.58
131	13.16	25.24	37.00	48.47	59.03	69.12	78.71	87.58
132	13.16	25.25	37.01	48.48	59.03	69.12	78.72	87.60
133	13.16	25.25	37.01	48.48	59.04	69.13	78.73	87.61
134	13.16	25.25	37.01	48.49	59.04	69.14	78.74	87.61
135	13.17	25.25	37.02	48.50	59.05	69.15	78.75	87.63
136	13.16	25.25	37.02	48.49	59.05	69.15	78.75	87.63
137	13.17	25.26	37.02	48.50	59.06	69.16	78.76	87.65
138	13.17	25.26	37.03	48.51	59.07	69.17	78.78	87.67
139	13.17	25.26	37.03	48.51	59.07	69.18	78.79	87.68
140	13.18	25.27	37.04	48.53	59.09	69.20	78.81	87.70
141	13.18	25.27	37.05	48.53	59.10	69.21	78.82	87.72
142	13.17	25.27	37.05	48.54	59.10	69.21	78.83	87.73
143	13.18	25.27	37.05	48.54	59.12	69.23	78.85	87.75
144	13.18	25.28	37.06	48.56	59.13	69.24	78.87	87.77
145	13.19	25.29	37.07	48.57	59.14	69.26	78.89	87.80
146	13.18	25.28	37.07	48.57	59.14	69.27	78.89	87.81
147	13.19	25.29	37.08	48.58	59.17	69.29	78.93	87.84
148	13.19	25.30	37.09	48.59	59.18	69.31	78.94	87.86
149	13.18	25.30	37.09	48.60	59.19	69.32	78.96	87.88
150	13.20	25.31	37.11	48.62	59.21	69.34	78.99	87.92
151	13.19	25.31	37.12	48.63	59.23	69.37	79.02	87.96
152	13.20	25.32	37.13	48.65	59.25	69.40	79.05	88.00
153	13.20	25.33	37.14	48.66	59.27	69.42	79.08	88.03
154	13.20	25.33	37.14	48.67	59.28	69.44	79.11	88.06
155	13.21	25.34	37.16	48.69	59.31	69.47	79.14	88.10
156	13.21	25.35	37.17	48.71	59.33	69.50	79.18	88.14
157	13.22	25.36	37.19	48.73	59.35	69.52	79.21	88.19
158	13.22	25.37	37.20	48.74	59.37	69.55	79.24	88.22
159	13.22	25.37	37.20	48.76	59.39	69.57	79.27	88.26
160	13.22	25.38	37.22	48.77	59.41	69.60	79.31	88.30
161	13.23	25.39	37.23	48.79	59.44	69.63	79.34	88.35
162	13.23	25.39	37.24	48.80	59.45	69.65	79.37	88.38
163	13.23	25.40	37.25	48.81	59.47	69.67	79.39	88.41
164	13.24	25.41	37.27	48.84	59.50	69.70	79.43	88.45
165	13.25	25.42	37.27	48.85	59.51	69.73	79.46	88.48
166	13.24	25.42	37.28	48.86	59.53	69.74	79.48	88.51
167	13.24	25.42	37.29	48.87	59.54	69.76	79.50	88.54
168	13.25	25.43	37.30	48.88	59.56	69.79	79.53	88.57
169	13.26	25.44	37.31	48.90	59.58	69.81	79.56	88.60
170	13.26	25.45	37.32	48.91	59.60	69.83	79.58	88.63
171	13.26	25.44	37.32	48.91	59.60	69.84	79.59	88.64
172	13.26	25.45	37.33	48.92	59.61	69.85	79.61	88.66
173	13.26	25.46	37.34	48.93	59.63	69.87	79.63	88.68
174	13.27	25.46	37.34	48.94	59.64	69.88	79.64	88.70
175	13.26	25.46	37.34	48.94	59.64	69.89	79.65	88.71
176	13.26	25.46	37.35	48.95	59.64	69.89	79.66	88.72
177	13.27	25.47	37.36	48.96	59.66	69.91	79.67	88.74
178	13.26	25.46	37.35	48.95	59.65	69.90	79.67	88.74
179	13.27	25.47	37.36	48.96	59.66	69.91	79.68	88.75
180	13.26	25.46	37.35	48.96	59.66	69.91	79.68	88.74

TABLE III

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 0 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.0	
111					0.0	
112					0.02	
113					0.04	
114					0.07	
115					0.12	
116					0.16	
117					0.21	
118					0.28	
119					0.35	
120					0.43	
121					0.52	
122					0.62	
123					0.72	
124					0.84	
125					0.96	
126					1.09	
127					1.24	
128					1.39	
129					1.56	
130					1.73	
131					1.91	
132					2.10	
133					2.31	
134					2.53	
135					2.75	
136					3.00	
137					3.25	
138					3.52	
139					3.81	
140					4.10	
141					4.41	
142					4.75	
143					5.10	
144					5.46	
145	-6.59	0.01	-0.74	6.60	5.85	-0.75
146	-4.98	0.46	1.28	5.44	6.26	0.82
147	-3.24	1.34	3.44	4.58	6.68	2.10
148	-1.40	2.41	5.73	3.81	7.13	3.32
149	0.51	3.66	8.13	3.15	7.62	4.47
150	2.49	5.01	10.60	2.52	8.11	5.59
151	4.50	6.47	13.15	1.97	8.65	6.68
152	6.55	8.04	15.77	1.49	9.22	7.73
153	8.65	9.72	18.47	1.07	9.82	8.75
154	10.78	11.50	21.25	0.72	10.47	9.75
155	12.93	13.38	24.08	0.45	11.15	10.70
156	15.10	15.35	26.98	0.25	11.88	11.63
157	17.31	17.41	29.95	0.10	12.64	12.54
158	19.53	19.55	32.98	0.02	13.45	13.43
159			36.09			
160			39.25			
161			42.49			
162			45.79			
163			49.15			
164			52.56			
165			56.04			
166			59.59			
167			63.19			
168			66.85			
169			70.57			
170			74.35			
171			78.21			
172			82.13			
173			86.11			
174			90.15			
175			94.27			
176			98.45			
177			102.69			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDESSON MODEL B1)

DEPTH = 100 KM

DEPTH	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					-0.01	
111					0.01	
112					0.02	
113					0.05	
114					0.08	
115					0.12	
116					0.16	
117					0.22	
118					0.29	
119					0.36	
120					0.44	
121					0.54	
122					0.63	
123					0.73	
124					0.85	
125					0.98	
126					1.11	
127					1.26	
128					1.41	
129					1.58	
130					1.75	
131					1.93	
132					2.13	
133					2.33	
134					2.55	
135					2.78	
136					3.02	
137					3.28	
138					3.55	
139					3.84	
140					4.14	
141					4.46	
142					4.79	
143					5.15	
144					5.51	
145	-6.30	0.03	-0.40	6.33	5.90	-0.43
146	-4.67	0.63	1.64	5.30	6.31	1.01
147	-2.90	1.55	3.84	4.45	6.74	2.29
148	-1.03	2.68	6.16	3.71	7.19	3.48
149	0.89	3.94	8.56	3.05	7.67	4.62
150	2.88	5.31	11.06	2.43	8.18	5.75
151	4.90	6.80	13.61	1.90	8.71	6.81
152	6.98	8.40	16.26	1.42	9.28	7.86
153	9.08	10.09	18.97	1.01	9.89	8.88
154	11.21	11.89	21.75	0.68	10.54	9.86
155	13.37	13.78	24.60	0.41	11.23	10.82
156	15.56	15.78	27.51	0.22	11.95	11.73
157	17.77	17.85	30.49	0.08	12.72	12.64
158	19.99	20.00	33.53	0.01	13.54	13.53
159			36.64			
160			39.82			
161			43.07			
162			46.37			
163			49.74			
164			53.16			
165			56.65			
166			60.19			
167			63.79			
168			67.46			
169			71.19			
170			74.98			
171			78.84			
172			82.76			
173			86.74			
174			90.79			
175			94.90			
176			99.09			
177			103.34			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 200 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.0	
111					0.01	
112					0.02	
113					0.04	
114					0.08	
115					0.13	
116					0.17	
117					0.23	
118					0.30	
119					0.38	
120					0.45	
121					0.54	
122					0.64	
123					0.75	
124					0.87	
125					1.00	
126					1.13	
127					1.28	
128					1.43	
129					1.60	
130					1.77	
131					1.96	
132					2.16	
133					2.37	
134					2.59	
135					2.81	
136					3.06	
137					3.32	
138					3.59	
139					3.88	
140					4.18	
141					4.50	
142					4.84	
143					5.19	
144					5.56	
145	-5.98	0.13	-0.03	6.11	5.95	-0.16
146	-4.30	0.84	2.06	5.14	6.36	1.22
147	-2.50	1.81	4.29	4.31	6.79	2.48
148	-0.61	2.98	6.64	3.59	7.25	3.66
149	1.33	4.27	9.07	2.94	7.74	4.80
150	3.33	5.66	11.57	2.33	8.24	5.91
151	5.37	7.18	14.15	1.81	8.78	6.97
152	7.44	8.79	16.80	1.35	9.36	8.01
153	9.55	10.51	19.53	0.96	9.98	9.02
154	11.71	12.34	22.33	0.63	10.62	9.99
155	13.87	14.25	25.19	0.38	11.32	10.94
156	16.06	16.26	28.11	0.20	12.05	11.85
157	18.28	18.35	31.10	0.07	12.82	12.75
158	20.52	20.53	34.16	0.01	13.64	13.63
159			37.27			
160			40.46			
161			43.71			
162			47.02			
163			50.40			
164			53.82			
165			57.32			
166			60.87			
167			64.47			
168			68.14			
169			71.88			
170			75.67			
171			79.53			
172			83.46			
173			87.45			
174			91.50			
175			95.62			
176			99.80			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL 31)

DEPTH = 300 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.0	
111					0.01	
112					0.03	
113					0.05	
114					0.09	
115					0.13	
116					0.17	
117					0.24	
118					0.30	
119					0.38	
120					0.47	
121					0.56	
122					0.66	
123					0.77	
124					0.89	
125					1.02	
126					1.15	
127					1.30	
128					1.46	
129					1.62	
130					1.80	
131					1.99	
132					2.19	
133					2.39	
134					2.62	
135					2.85	
136					3.10	
137					3.35	
138					3.63	
139					3.92	
140					4.22	
141					4.55	
142					4.89	
143					5.24	
144					5.61	
145	-5.63	0.27	0.38	5.90	6.01	0.11
146	-3.90	1.07	2.52	4.97	6.42	1.45
147	-2.08	2.09	4.78	4.17	6.86	2.69
148	-0.17	3.31	7.15	3.48	7.32	3.84
149	1.80	4.62	9.60	2.82	7.80	4.98
150	3.80	6.04	12.12	2.24	8.32	6.08
151	5.86	7.58	14.72	1.72	8.86	7.14
152	7.95	9.22	17.39	1.27	9.44	8.17
153	10.07	10.97	20.13	0.90	10.06	9.16
154	12.22	12.81	22.93	0.59	10.71	10.12
155	14.40	14.74	25.81	0.34	11.41	11.07
156	16.61	16.78	28.75	0.17	12.14	11.97
157	18.83	18.88	31.75	0.05	12.92	12.87
158	21.07	21.07	34.81	0.0	13.74	13.74
159			37.93			
160			41.14			
161			44.40			
162			47.72			
163			51.10			
164			54.54			
165			58.02			
166			61.58			
167			65.20			
168			68.87			
169			72.61			
170			76.41			
171			80.27			
172			84.20			
173			88.20			
174			92.25			
175			96.37			
176			100.57			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 400 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.0	
111					0.01	
112					0.03	
113					0.05	
114					0.09	
115					0.14	
116					0.19	
117					0.24	
118					0.32	
119					0.40	
120					0.48	
121					0.57	
122					0.68	
123					0.78	
124					0.91	
125					1.03	
126					1.18	
127					1.33	
128					1.48	
129					1.65	
130					1.83	
131					2.01	
132					2.22	
133					2.42	
134					2.65	
135					2.89	
136					3.13	
137					3.39	
138					3.67	
139					3.96	
140					4.28	
141					4.59	
142					4.94	
143					5.29	
144	-6.85	0.01	-1.17	6.86	5.68	-1.18
145	-5.23	0.46	0.84	5.69	6.07	0.38
146	-3.47	1.34	3.02	4.81	6.49	1.68
147	-1.62	2.40	5.30	4.02	6.92	2.90
148	0.31	3.65	7.69	3.34	7.38	4.04
149	2.29	5.00	10.17	2.71	7.88	5.17
150	4.32	6.45	12.71	2.13	8.39	6.26
151	6.39	8.03	15.33	1.64	8.94	7.30
152	8.49	9.69	18.02	1.20	9.53	8.33
153	10.62	11.46	20.77	0.84	10.15	9.31
154	12.78	13.32	23.59	0.54	10.81	10.27
155	14.97	15.28	26.48	0.31	11.51	11.20
156	17.18	17.33	29.43	0.15	12.25	12.10
157	19.41	19.45	32.44	0.04	13.03	12.99
158	19.41		35.51		13.03	
159			38.66			
160			41.85			
161			45.13			
162			48.45			
163			51.84			
164			55.29			
165			58.79			
166			62.35			
167			65.97			
168			69.64			
169			73.39			
170			77.19			
171			81.06			
172			84.99			
173			88.98			
174			93.04			
175			97.17			
176			101.37			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 500 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-PC	CD-DF	BC-DF
110					0.0	
111					0.01	
112					0.03	
113					0.07	
114					0.10	
115					0.14	
116					0.20	
117					0.26	
118					0.33	
119					0.41	
120					0.50	
121					0.59	
122					0.69	
123					0.81	
124					0.93	
125					1.06	
126					1.20	
127					1.35	
128					1.51	
129					1.68	
130					1.85	
131					2.06	
132					2.25	
133					2.47	
134					2.69	
135					2.93	
136					3.18	
137					3.44	
138					3.72	
139					4.01	
140					4.33	
141					4.65	
142					4.99	
143					5.36	
144	-6.45	0.07	-0.71	6.52	5.74	-0.78
145	-4.76	0.71	1.37	5.47	6.13	0.66
146	-2.97	1.65	3.58	4.62	6.55	1.93
147	-1.08	2.79	5.92	3.87	7.00	3.13
148	0.86	4.06	8.33	3.20	7.47	4.27
149	2.86	5.44	10.82	2.58	7.96	5.38
150	4.91	6.94	13.39	2.03	8.48	6.45
151	6.99	8.53	16.02	1.54	9.03	7.49
152	9.11	10.23	18.73	1.12	9.62	8.50
153	11.25	12.02	21.50	0.77	10.25	9.48
154	13.42	13.91	24.33	0.49	10.91	10.42
155	15.62	15.89	27.24	0.27	11.62	11.35
156	17.84	17.96	30.20	0.12	12.36	12.24
157	20.08	20.10	33.22	0.02	13.14	13.12
158	20.08		36.31		13.14	
159			39.45			
160			42.67			
161			45.96			
162			49.29			
163			52.69			
164			56.14			
165			59.64			
166			63.22			
167			66.84			
168			70.52			
169			74.27			
170			78.09			
171			81.95			
172			85.89			
173			89.90			
174			93.96			
175			98.09			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 600 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.0	
111					0.01	
112					0.03	
113					0.07	
114					0.11	
115					0.15	
116					0.21	
117					0.28	
118					0.34	
119					0.42	
120					0.51	
121					0.61	
122					0.71	
123					0.83	
124					0.95	
125					1.08	
126					1.23	
127					1.38	
128					1.55	
129					1.72	
130					1.89	
131					2.09	
132					2.29	
133					2.51	
134					2.74	
135					2.98	
136					3.23	
137					3.49	
138					3.77	
139					4.07	
140					4.39	
141					4.72	
142					5.06	
143					5.43	
144	-5.98	0.23	-0.18	6.21	5.80	-0.41
145	-4.25	1.01	1.96	5.26	6.21	0.95
146	-2.42	2.01	4.22	4.43	6.64	2.21
147	-0.50	3.21	6.58	3.71	7.08	3.37
148	1.48	4.53	9.03	3.05	7.55	4.50
149	3.49	5.94	11.54	2.45	8.05	5.60
150	5.56	7.47	14.12	1.91	8.56	6.65
151	7.65	9.09	16.78	1.44	9.13	7.69
152	9.78	10.82	19.51	1.04	9.73	8.69
153	11.94	12.65	22.30	0.71	10.36	9.65
154	14.12	14.56	25.15	0.44	11.03	10.59
155	16.32	16.56	28.06	0.24	11.74	11.50
156	18.55	18.65	31.04	0.10	12.49	12.39
157	20.80	20.81	34.07	0.01	13.27	13.26
158	20.80		37.18		13.27	
159			40.33			
160			43.57			
161			46.86			
162			50.20			
163			53.60			
164			57.06			
165			60.58			
166			64.15			
167			67.78			
168			71.48			
169			75.23			
170			79.05			
171			82.93			
172			86.86			
173			90.88			
174			94.94			
175			99.08			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 700 KM

DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.01	
111					0.02	
112					0.05	
113					0.08	
114					0.11	
115					0.16	
116					0.22	
117					0.28	
118					0.36	
119					0.44	
120					0.54	
121					0.63	
122					0.73	
123					0.85	
124					0.98	
125					1.11	
126					1.26	
127					1.41	
128					1.58	
129					1.75	
130					1.93	
131					2.13	
132					2.33	
133					2.55	
134					2.79	
135					3.03	
136					3.28	
137					3.54	
138					3.83	
139					4.14	
140					4.45	
141					4.78	
142					5.13	
143	-7.09	0.01	-1.59	7.10	5.50	-1.60
144	-5.45	0.48	0.44	5.93	5.89	-0.04
145	-3.66	1.37	2.63	5.03	6.29	1.26
146	-1.78	2.45	4.93	4.23	6.71	2.48
147	0.15	3.69	7.33	3.54	7.18	3.64
148	2.15	5.04	9.79	2.89	7.64	4.75
149	4.19	6.50	12.34	2.31	8.15	5.84
150	6.27	8.06	14.94	1.79	8.67	6.88
151	8.38	9.72	17.62	1.34	9.24	7.90
152	10.52	11.48	20.36	0.96	9.84	8.88
153	12.69	13.33	23.17	0.64	10.48	9.84
154	14.89	15.28	26.05	0.39	11.16	10.77
155	17.11	17.31	28.98	0.20	11.87	11.67
156	19.35	19.43	31.98	0.08	12.63	12.55
157	21.60	21.61	35.02	0.01	13.42	13.41
158	21.60		38.13		13.42	
159			41.31			
160			44.56			
161			47.85			
162			51.21			
163			54.61			
164			58.08			
165			61.61			
166			65.19			
167			68.83			
168			72.52			
169			76.29			
170			80.11			
171			83.99			
172			87.94			
173			91.95			
174			96.02			

TABLE III (Continued)

TRAVEL TIME DIFFERENCES OF PKP BRANCH
(JORDAN AND ANDERSON MODEL B1)

DEPTH = 800 KM						
DELTA	AB-CD	AB-BC	AB-DF	CD-BC	CD-DF	BC-DF
110					0.01	
111					0.03	
112					0.05	
113					0.08	
114					0.12	
115					0.18	
116					0.23	
117					0.30	
118					0.37	
119					0.46	
120					0.55	
121					0.65	
122					0.76	
123					0.88	
124					1.01	
125					1.14	
126					1.29	
127					1.45	
128					1.62	
129					1.79	
130					1.98	
131					2.17	
132					2.39	
133					2.61	
134					2.83	
135					3.08	
136					3.33	
137					3.61	
138					3.90	
139					4.21	
140					4.52	
141					4.86	
142					5.21	
143	-6.53	0.14	-0.95	6.67	5.58	-1.09
144	-4.81	0.83	1.16	5.64	5.97	0.33
145	-2.98	1.81	3.41	4.79	6.39	1.60
146	-1.07	2.95	5.75	4.02	6.82	2.80
147	0.91	4.26	8.18	3.35	7.27	3.92
148	2.93	5.64	10.67	2.71	7.74	5.03
149	4.99	7.14	13.24	2.15	8.25	6.10
150	7.08	8.74	15.87	1.66	8.79	7.13
151	9.22	10.44	18.58	1.22	9.36	8.14
152	11.38	12.24	21.35	0.86	9.97	9.11
153	13.56	14.12	24.17	0.56	10.61	10.05
154	15.77	16.10	27.06	0.33	11.29	10.96
155	18.00	18.16	30.01	0.16	12.01	11.85
156	20.24	20.30	33.02	0.06	12.78	12.72
157	22.51	22.52	36.10	0.01	13.59	13.58
158	22.51		39.21		13.59	
159			42.41			
160			45.66			
161			48.98			
162			52.35			
163			55.77			
164			59.24			
165			62.77			
166			66.36			
167			70.01			
168			73.71			
169			77.48			
170			81.31			
171			85.19			
172			89.14			
173			93.16			
174			97.24			

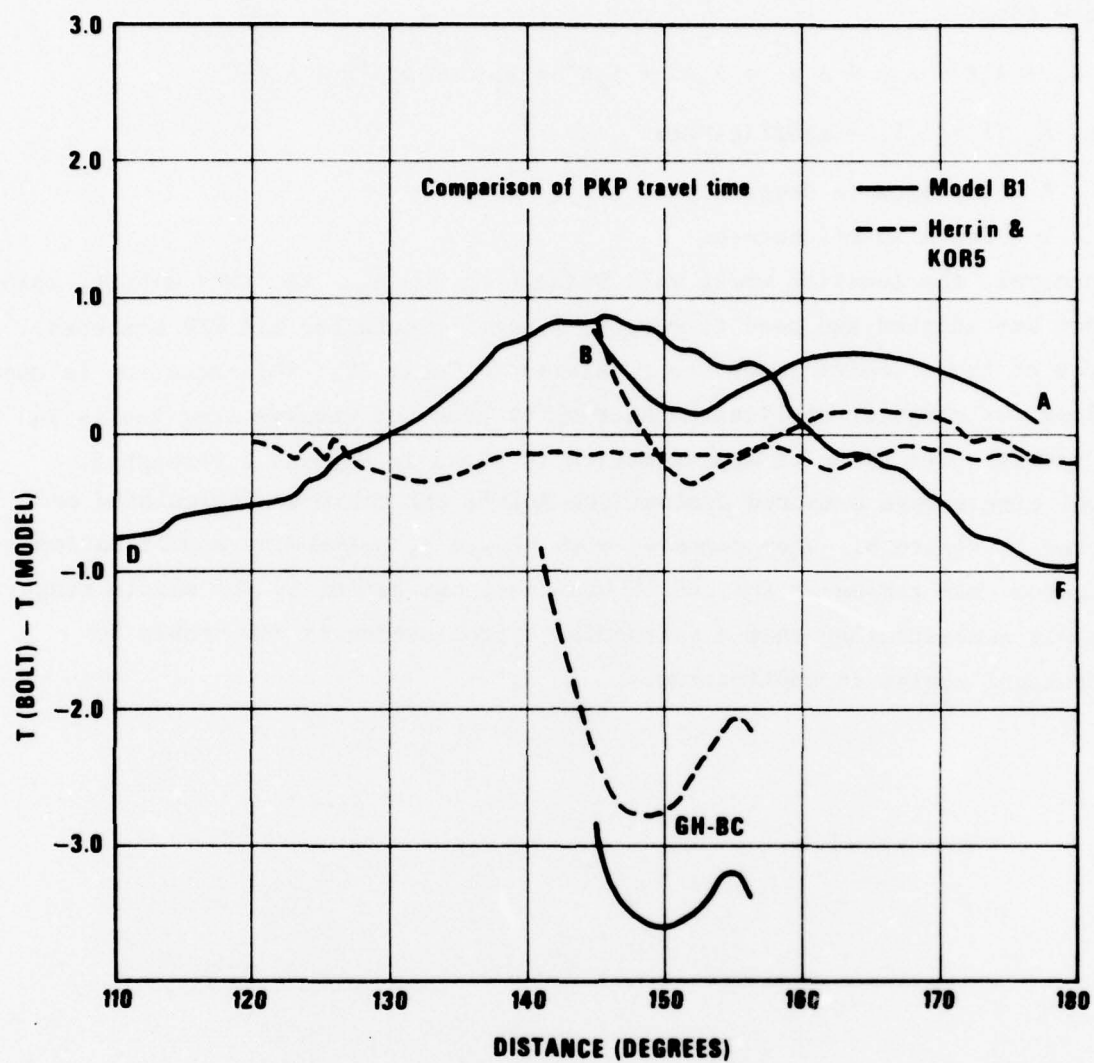


Figure 1. Comparison of theoretical PKP travel times with Bolt's PKP table.

POLYNOMIAL APPROXIMATION OF PKP TRAVEL TIMES

Teledyne Geotech (1968) developed a scheme to fit phase travel times with a polynomial approximation formula. The approximation equation was of the form:

$$T = A_1 + A_2\Delta + A_3h + A_4\Delta^2 + A_5\Delta h + A_6h^2 + A_7\Delta^3 + A_8\Delta^2h + A_9\Delta h^2$$

where A_i ($i = 1,9$) = coefficients

Δ = distance in degrees

h = depth in kilometers.

In general, the equation works well without A_8 and A_9 . For this report, this method was adopted and used to compute 7 coefficients for all PKP branches. Values of these coefficients are tabulated in Table IV. This equation is convenient for computer application because it does not require long tables in the memory. The error of approximation is shown in Figures 2 through 5. Travel time errors compared against the Bolt's PKP table are calculated and plotted in Figure 6. When compared with Figure 1, polynomial approximations are worse than tables at the end of branches, but better in the middle range, a result demonstrating that a polynomial approximation is comparable to theoretical tables in application.

Geotech, 1968, Equations for computing phase travel-times, Appendix 3 to Technical Report No. 68-28, Garland, Texas.

TABLE IV

Coefficients for PKP travel times with polynomial approximation equation

$$T - A_1 + A_2\Delta + A_3h + A_4\Delta^2 + A_5\Delta h + A_6h^2 + A_7\Delta^3$$

	PKP-AB	PKP-BC	PKP-CD	PKP-DF
A1	2.1874609×10^3	-1.1490044×10^3	1.0514683×10^3	1.3269504×10^3
A2	-2.5718964×10^1	3.4283463×10^1	-1.3772001×10^0	-8.2053394×10^0
A3	$-1.3882348 \times 10^{-1}$	-1.0637046×10^1	$-1.3236269 \times 10^{-1}$	$-1.2812320 \times 10^{-1}$
A4	1.8305379×10^{-1}	$-1.6313869 \times 10^{-1}$	2.3578446×10^{-3}	8.0502689×10^{-2}
A5	6.9567846×10^{-5}	$-1.5998328 \times 10^{-4}$	7.2037537×10^{-6}	$-2.6079055 \times 10^{-5}$
A6	3.1252393×10^{-5}	2.8213491×10^{-5}	2.7949800×10^{-5}	2.7583501×10^{-5}
A7	$-3.7085824 \times 10^{-4}$	2.5747227×10^{-4}	$-5.3665892 \times 10^{-5}$	$-2.1368316 \times 10^{-4}$

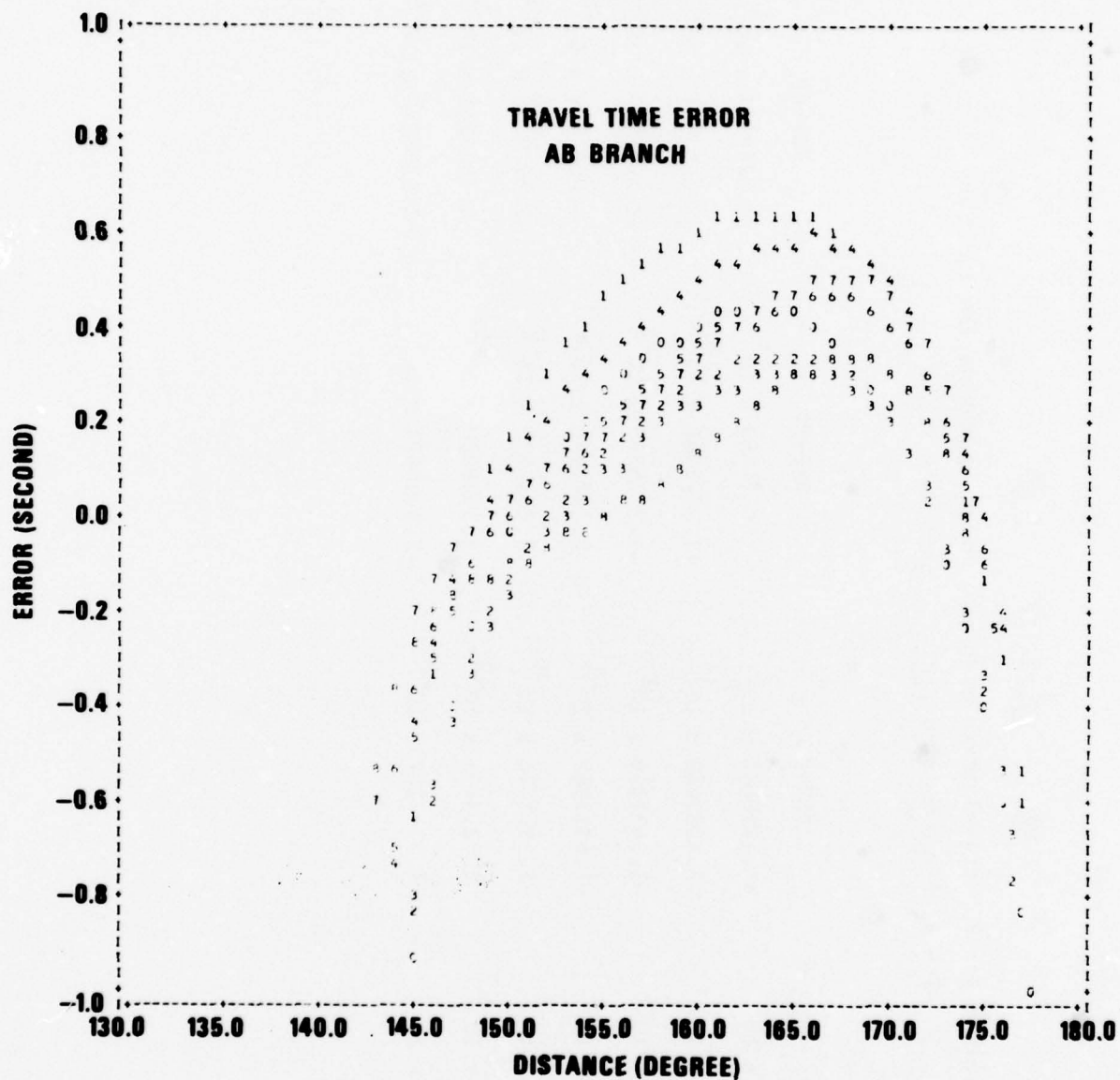


Figure 2. Travel time errors of PKP-AB branch computed with polynomial approximation. Numbers indicate depth of epicenter in hundreds of kilometers.

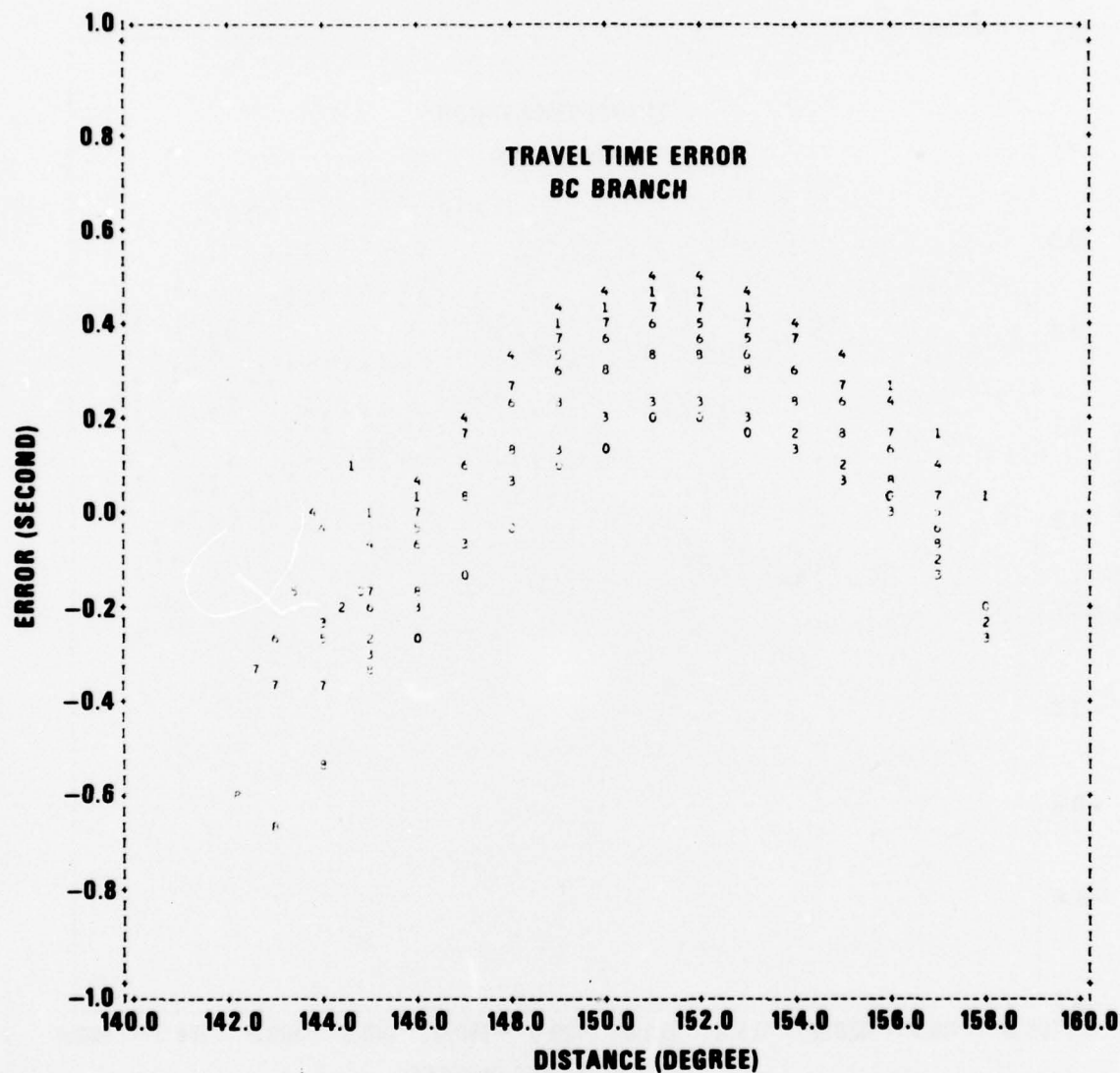


Figure 3. Travel time errors of PKP-BC branch computed with polynomial approximation. Numbers indicate depth of epicenter in hundreds of kilometers.

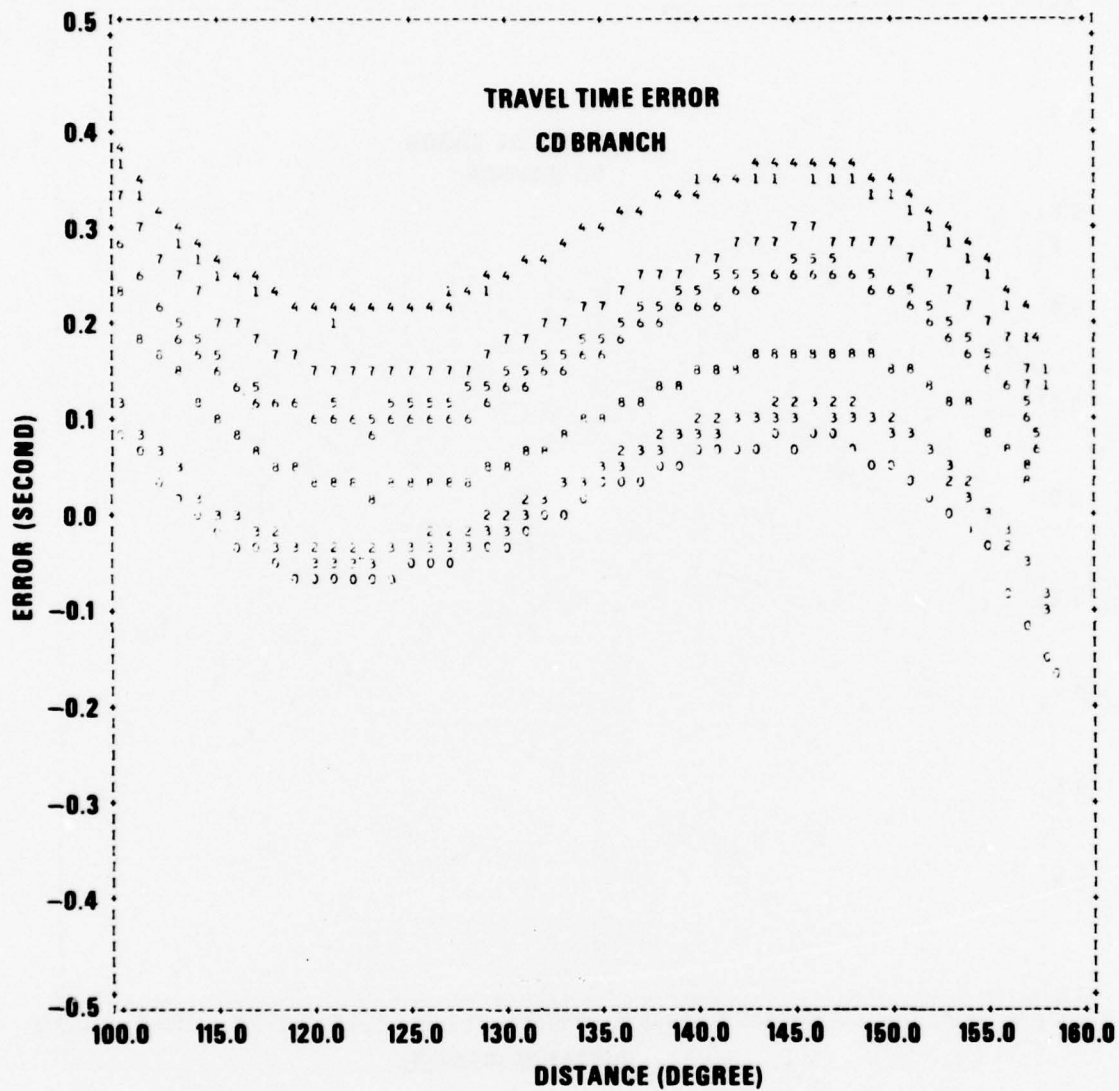


Figure 4. Travel time errors of PKP-CD branch computed with polynomial approximation. Numbers indicate depth of epicenter in hundreds of kilometers.

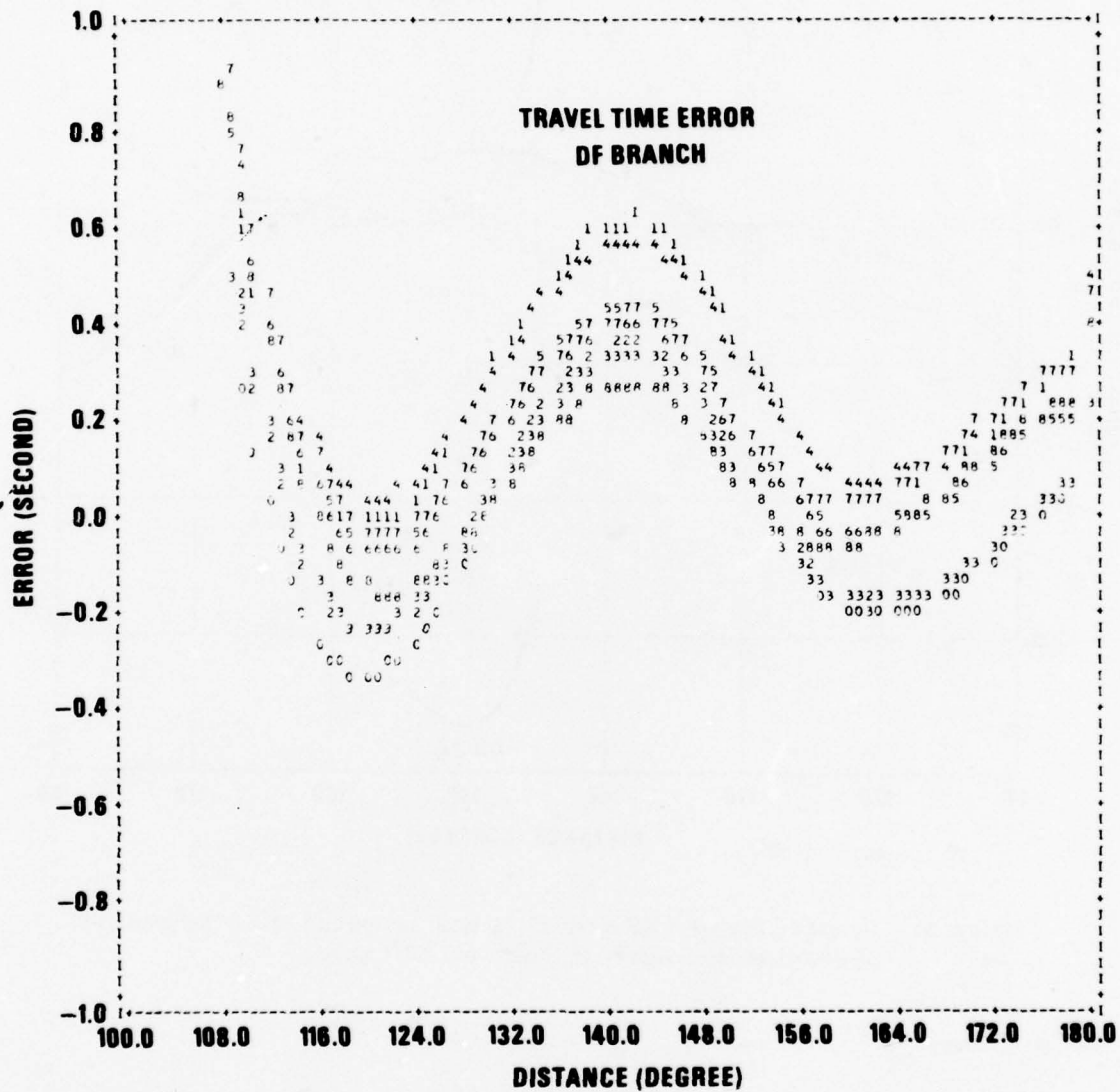


Figure 5. Travel time errors of PKP-DF branch computed with polynomial approximation. Numbers indicate depth of epicenter in hundreds of kilometers.

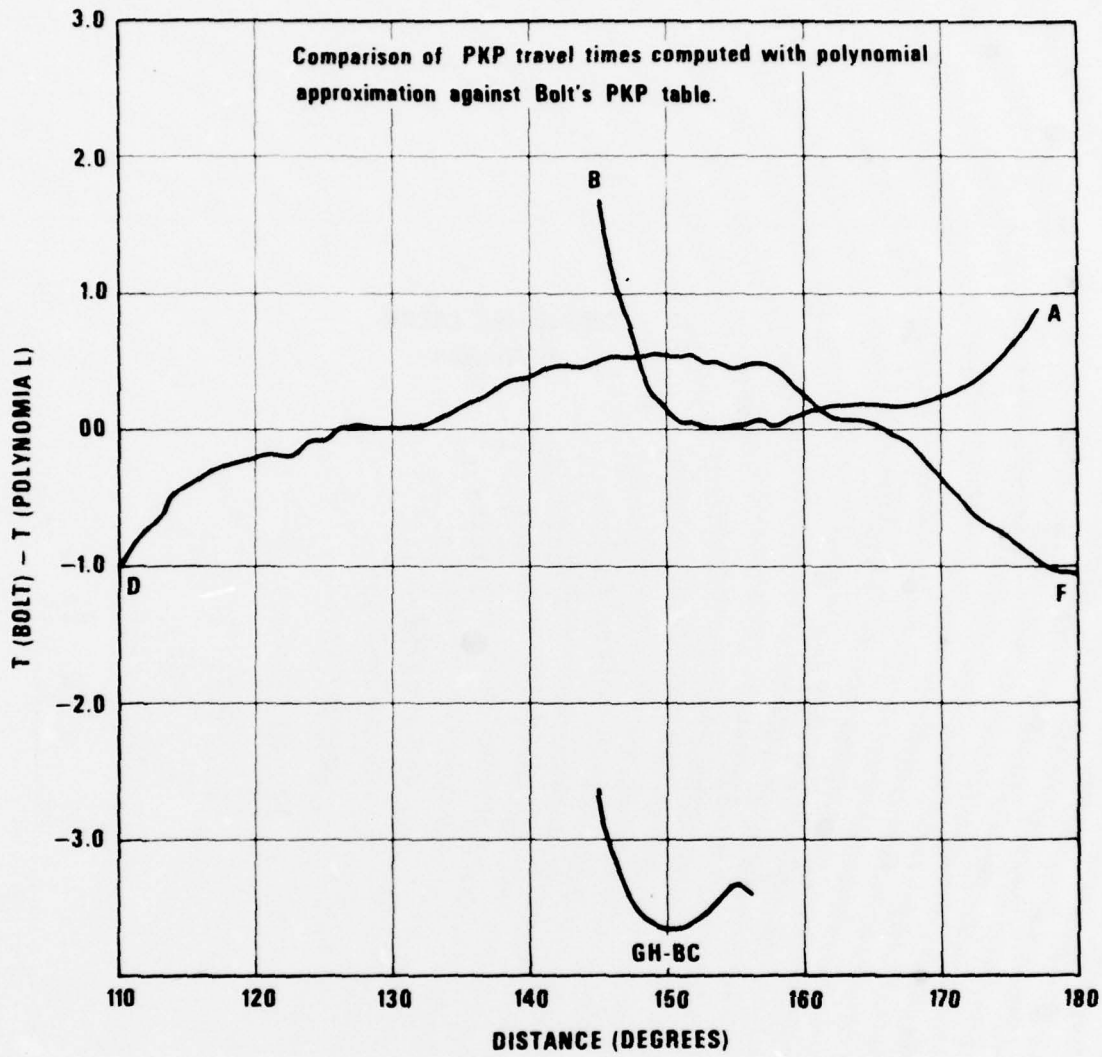


Figure 6. Comparison of PKP travel times computed with polynomial approximation against Bolt's PKP table.

B FACTORS FOR PKP

Perhaps because of the confusion in mixed branch arrivals, PKP amplitude-distance relationships are not well defined. Shurbet (1967) made a comprehensive study of PKP amplitudes for the range of 110° - 180° . For each event, he used the amplitude of the event at a station near 125° to normalize all observations. He encountered difficulty with multiple arrivals in the caustic zones; so, in general, his results give only the largest amplitude observed at a given distance. Engdahl (1968) reported some 70 PKP amplitudes with a comparable number of PKKP and related amplitudes from two earthquakes.

Sweetser and Blandford (1973) defined the PKP amplitude distance relationship by using $\log (A/T)$ of events reported by ISC bulletins, the VELA observatories, and LRSM station bulletins. Only shallow events were used in this study. Although this work is perhaps the most comprehensive study of PKP amplitudes to date, even this table is available only as a single value at each given distance in the caustic zone, and applies only to shallow events.

Computing theoretical PKP amplitudes depends not only upon the earth's velocity model but also upon the earth's anelastic attenuation (the Q model); Q models of the earth vary widely among researchers. To circumvent the uncertainties that Q models caused, we adjusted Q so that the calculated surface focus B factors fit Sweetser's and Blandford's results (1973).

Julian's ray tracing program, TVT6, allows us to compute the correct amplitudes of each ray taking account of divergence and anelastic absorption. We made a minor modification to this program to convert the amplitudes into B factors. The procedure can be described in two steps: 1) Veith's and Clawson's Q (1973) mantle model was used and B factors were computed for teleseismic P waves. Q values of each layer were then adjusted to obtain good

Shurbet, D. H., 1967, The earthquake P-phases which penetrate the earth's core; Bull. Seism. Soc. Am., 57, 875-890.

Sweetser, E. I., and R. R. Blandford, 1973, Seismic distance-amplitude relations for short period P, P_{diff} , PP, and compressional core phases for $\Delta > 90^{\circ}$; Teledyne Geotech, SDAC-TR-73-9, Alexandria, VA.

Veith, K. F., and G. E. Clawson, 1972, Magnitudes from short-period P-wave data; Bull. Seism. Soc. Am., 62, 435-452.

agreement between the theoretical B factors and Veith's and Clawson's observations; 2) we adopted the Q model at 1 Hz of Gilbert et al., (cited in Doornbos 1974, p. 409), and calculated B factors for PKP waves. Adjustments in the Q of the core were then made to match the resulting B factors for PKP-DF with those of Sweetser and Blandford, with the exception of the mixed branch amplitudes in the range of 145° to 158° .

Figure 7 compares the starting Q models of the mantle and the core, as well as the final result, with our adjustments. To match the rising B factors beyond 80° , values of Q are sharply lower at the lower mantle area. They are also somewhat lower in the inner core in order to match the result of Sweetser's and Blandford's B values.

Figures 8a and 8b show travel times and distance-amplitude relationships, respectively, for all PKP branches. Note that the amplitude of CD branch is larger than the DF branch's in the 110° - 151° range.

Theoretical B factors for nine depths for all PKP branches are shown in Figures 9 through 12; Table V gives the B factors for each branch for nine depths. For comparison, the practical B factors of Sweetser and Blandford are plotted in Figure 12.

Doornbos, D. J., 1974, The Anelasticity of the Inner Core; Geophys. J. R. Astr. Soc., 38, 397-415.

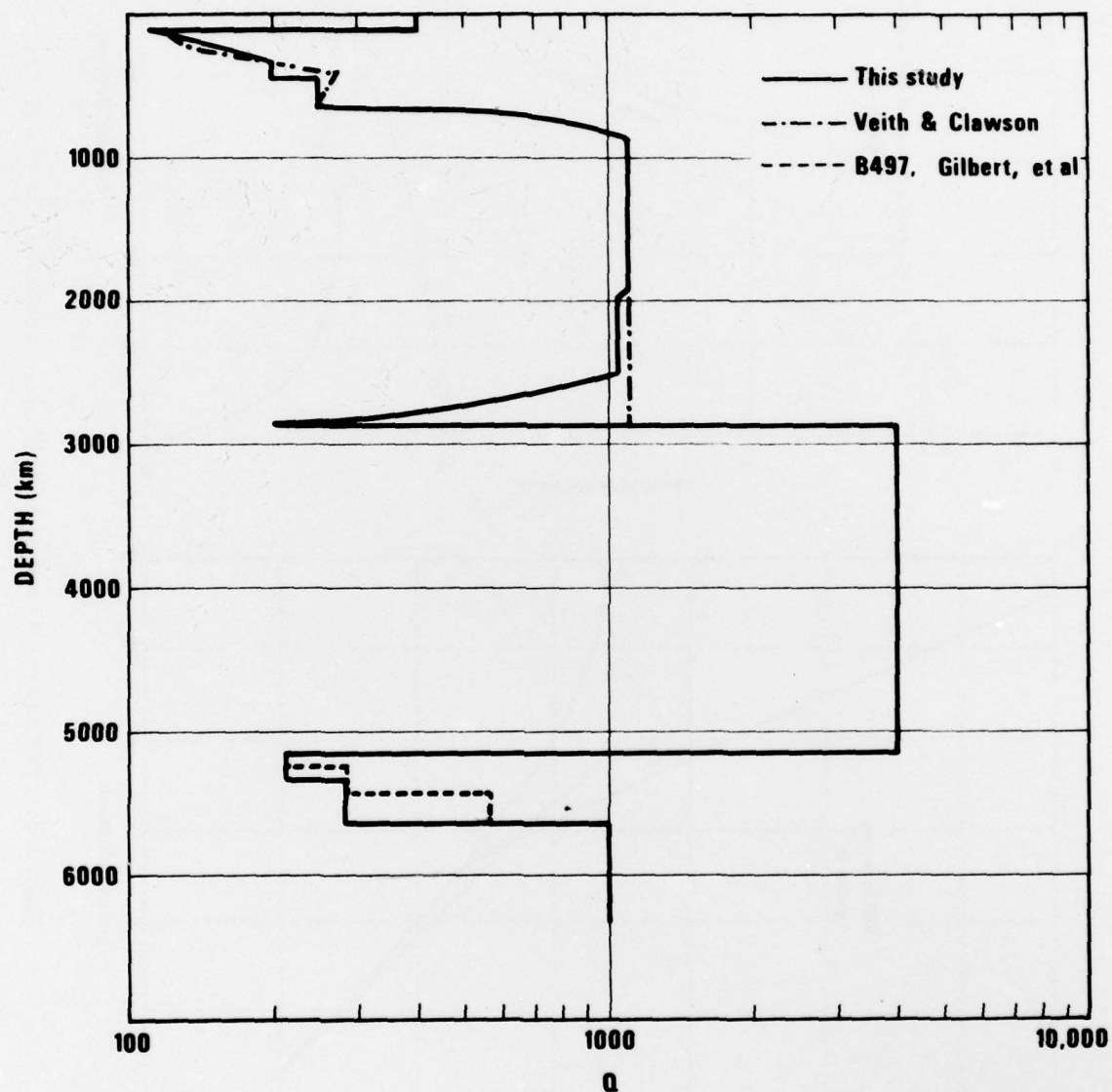


Figure 7. The Q model of the earth used in PKP amplitude computation as compared with Veith and Clawson's Mantle Q model and Doornbos' core Q model.

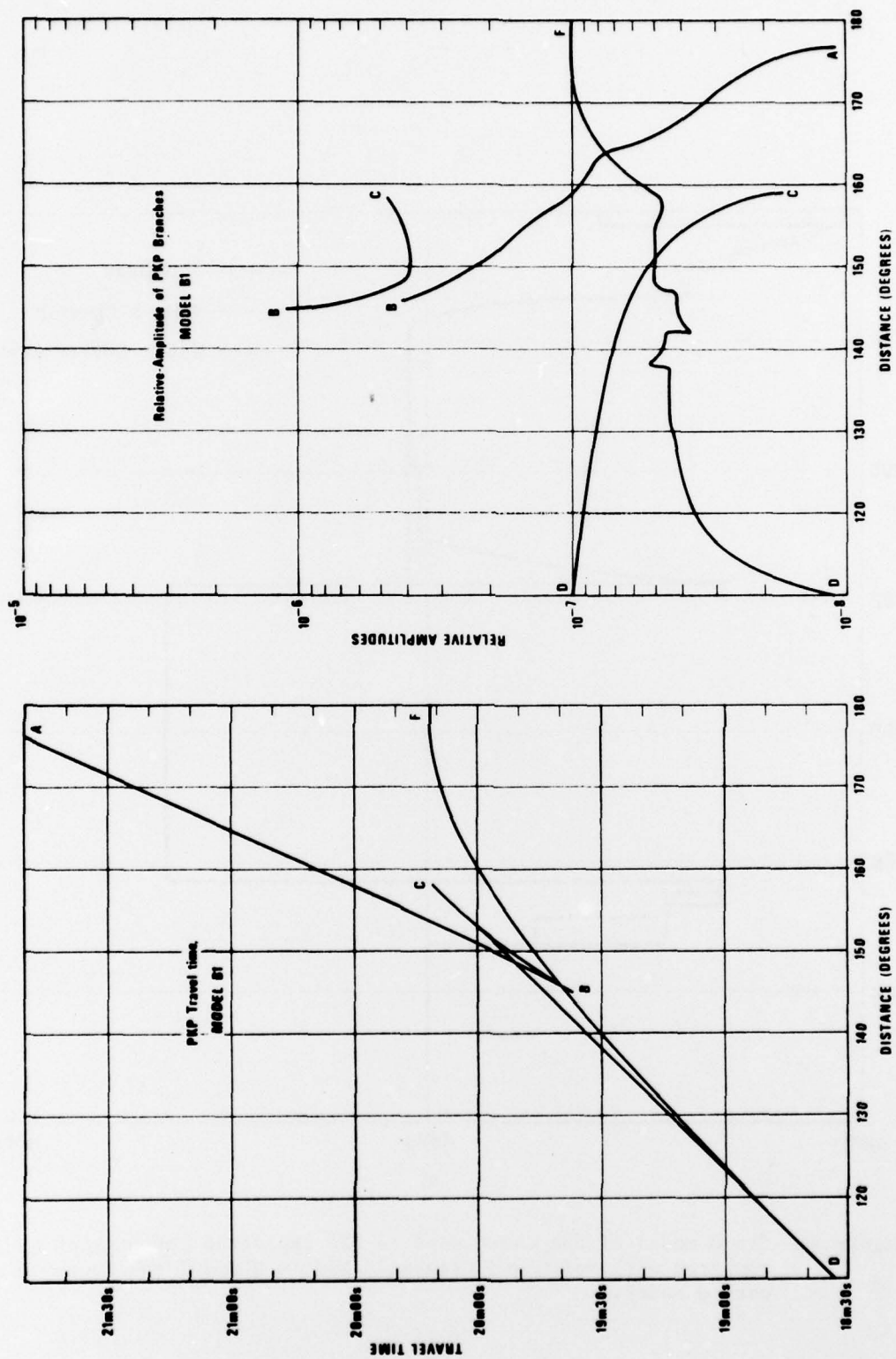


Figure 8. PKP travel times and amplitudes computed for model B1.

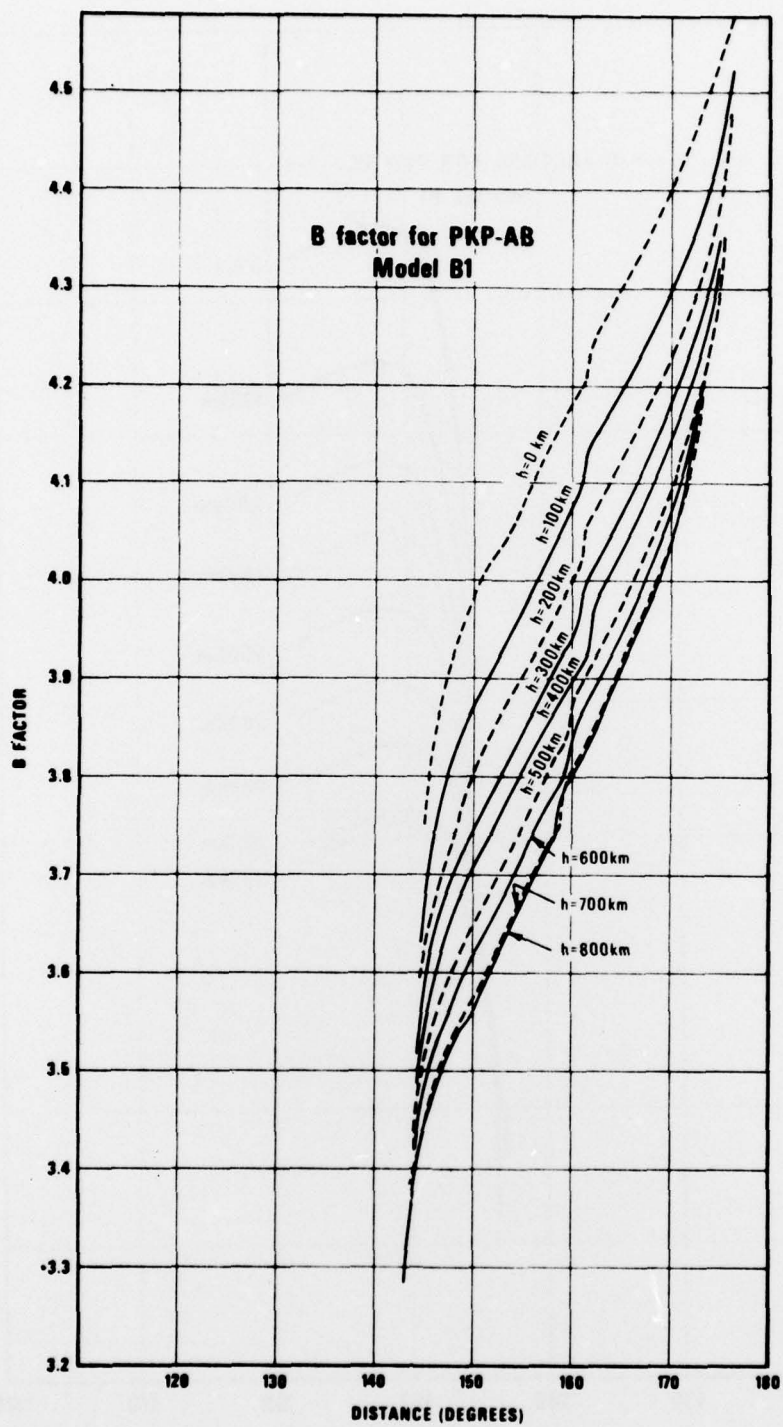


Figure 9. B factors for PKP-AB branch.

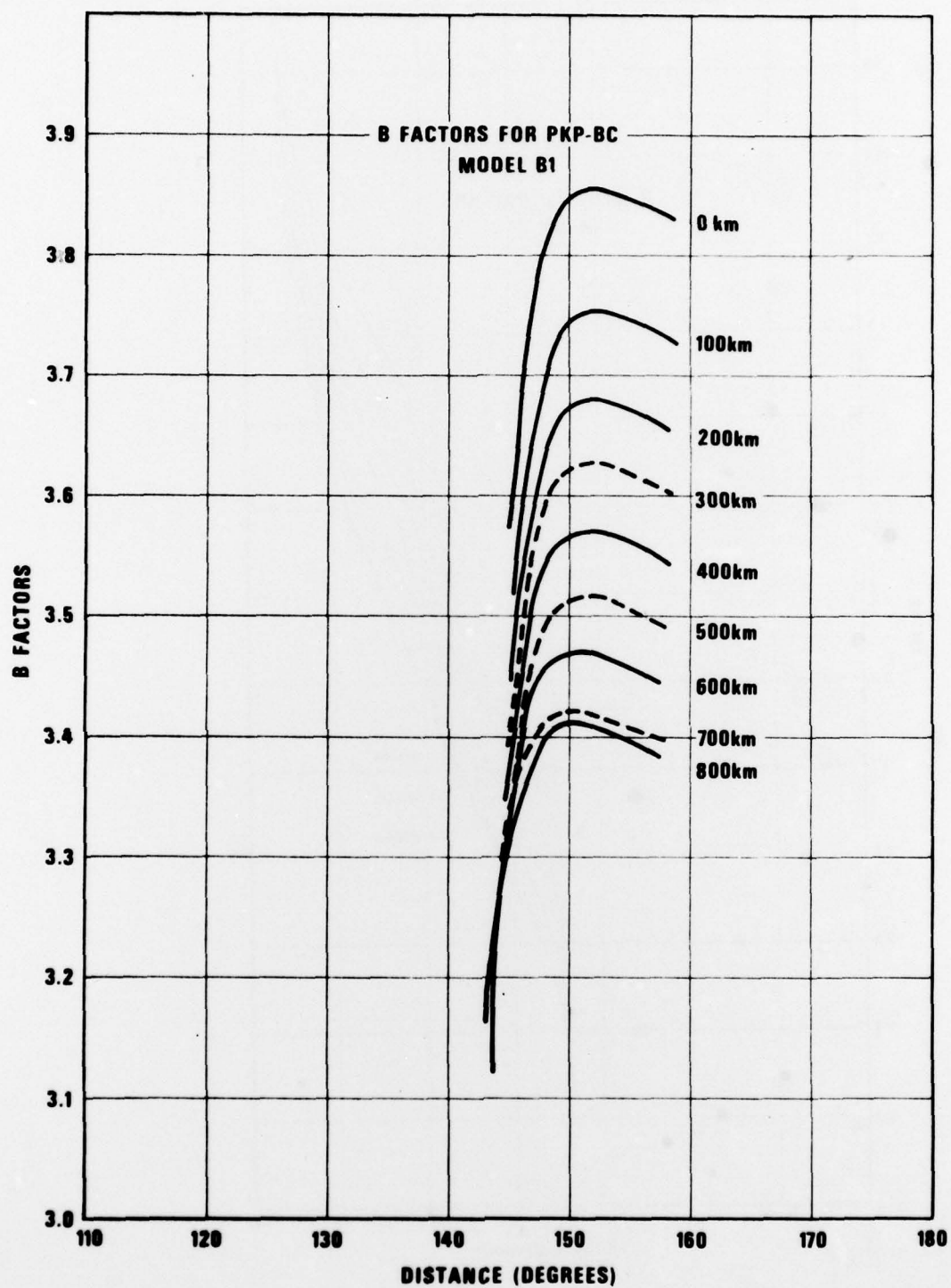


Figure 10. B factors for PKP-BC branch.

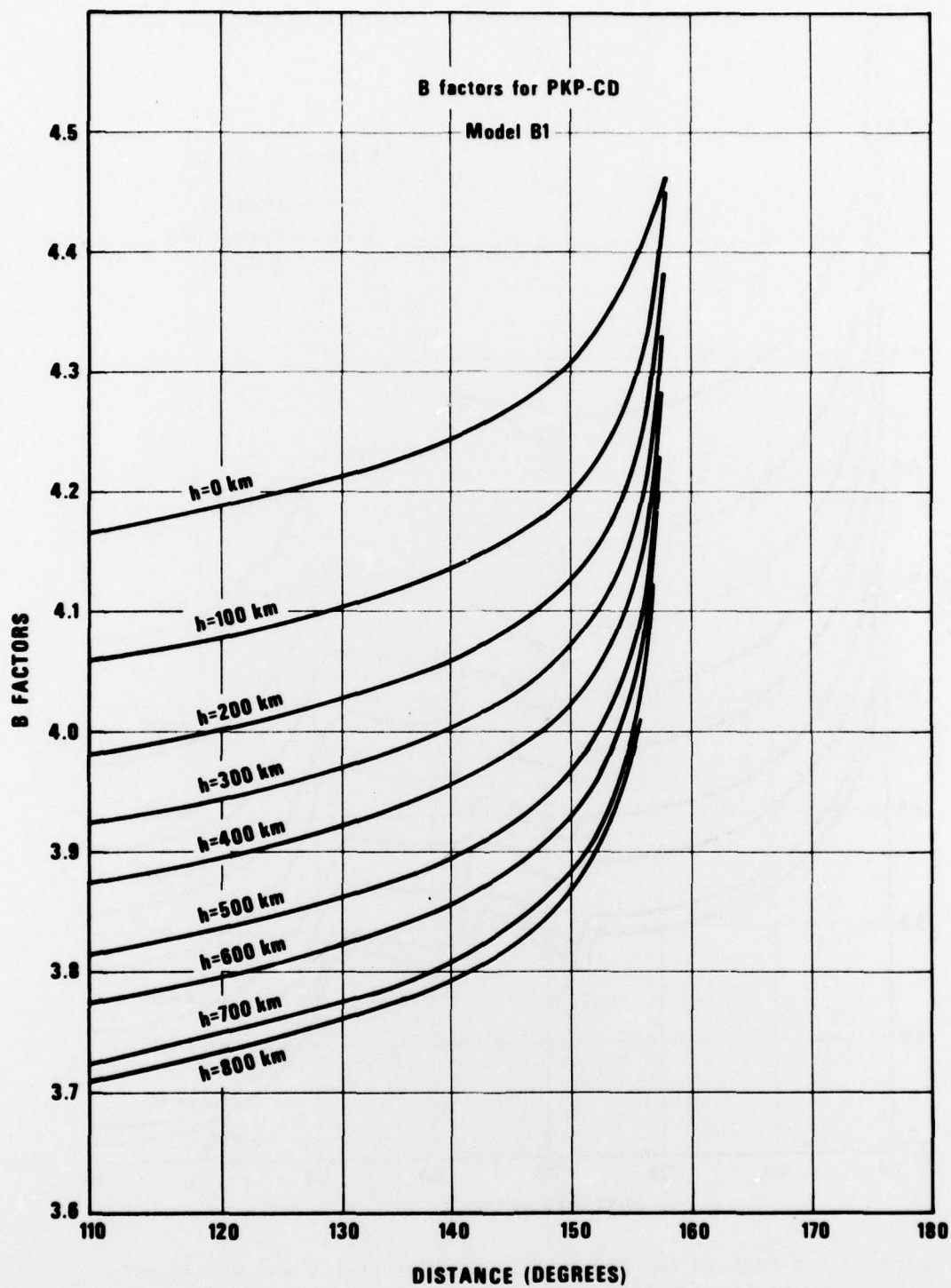


Figure 11. B factors for PKP-CD branch.

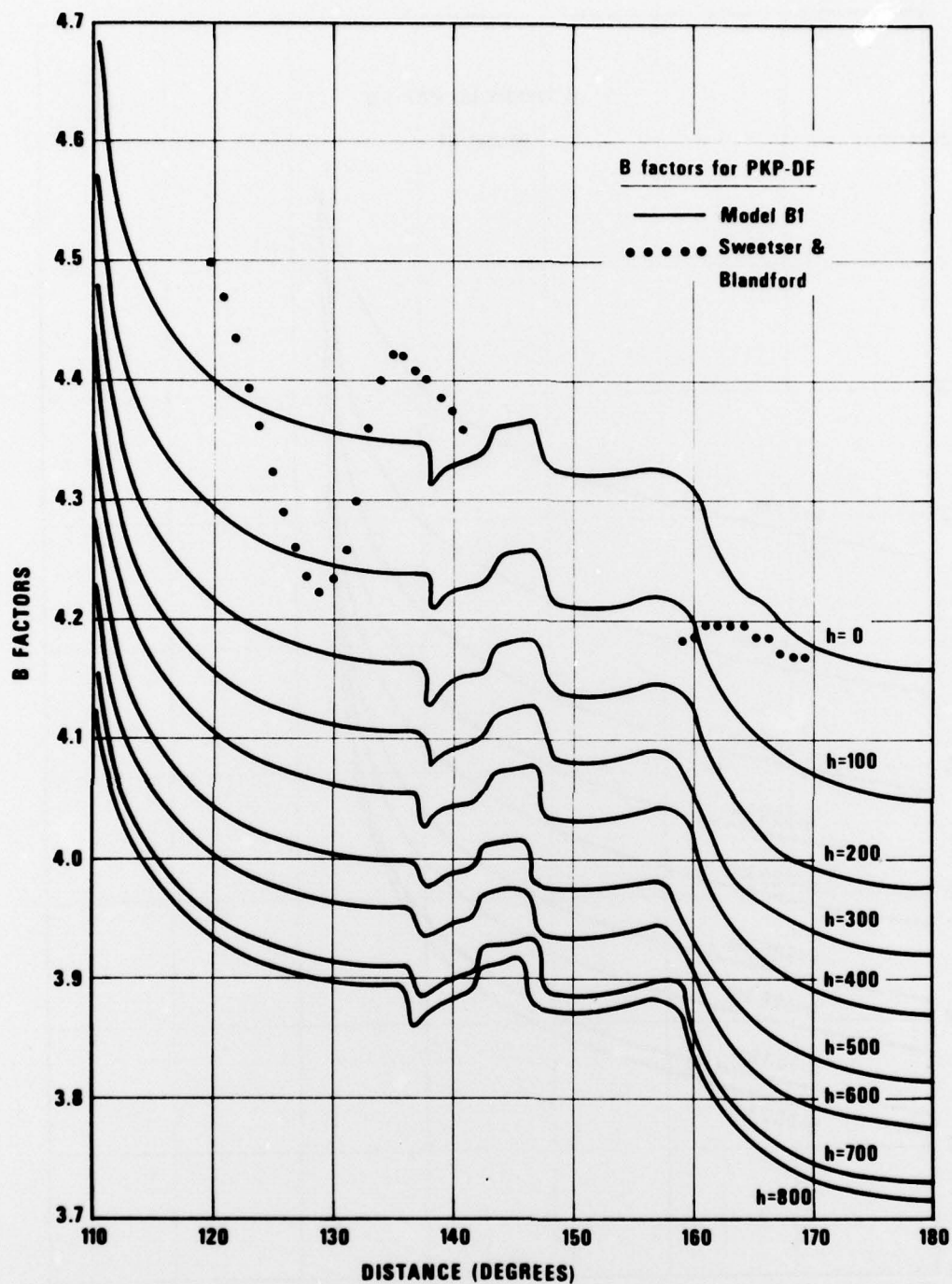


Figure 12. B factors for PKP-DF branch. Sweetser's and Blandford's practical B-factor for PKP are plotted in dotted line for comparison.

TABLE V
B Factors for PKP-AB

Δ	0	100	200	300	400	500	600	700	800
145	3.70	3.60	3.54	3.49	3.45	3.43	3.40	3.38	3.35
146	3.77	3.68	3.61	3.55	3.51	3.48	3.45	3.42	3.40
147	3.81	3.71	3.65	3.59	3.55	3.50	3.47	3.44	3.43
148	3.85	3.75	3.68	3.63	3.58	3.53	3.50	3.46	3.45
149	3.88	3.77	3.70	3.65	3.61	3.56	3.52	3.47	3.46
150	3.90	3.80	3.72	3.67	3.63	3.58	3.53	3.50	3.47
151	3.93	3.82	3.74	3.69	3.64	3.59	3.55	3.51	3.50
152	3.94	3.83	3.76	3.70	3.65	3.60	3.57	3.53	3.52
153	3.95	3.84	3.77	3.72	3.67	3.62	3.58	3.54	3.53
154	3.97	3.86	3.79	3.73	3.69	3.63	3.60	3.56	3.55
155	3.99	3.88	3.81	3.75	3.71	3.65	3.62	3.62	3.57
156	4.00	3.90	3.82	3.77	3.73	3.67	3.63	3.59	3.58
157	4.02	3.91	3.84	3.79	3.74	3.69	3.65	3.61	3.60
158	4.04	3.92	3.86	3.80	3.76	3.70	3.67	3.62	3.61
159	4.05	3.94	3.87	3.82	3.77	3.71	3.68	3.65	3.65
160	4.06	3.96	3.88	3.83	3.79	3.73	3.70	3.67	3.67
161	4.08	3.98	3.90	3.87	3.82	3.77	3.73	3.69	3.68
162	4.11	4.01	3.94	3.89	3.84	3.78	3.75	3.70	3.70
163	4.13	4.02	3.95	3.90	3.85	3.80	3.76	3.72	3.72
164	4.15	4.04	3.97	3.91	3.87	3.81	3.78	3.74	3.73
165	4.16	4.05	3.98	3.93	3.88	3.83	3.80	3.76	3.75
166	4.17	4.07	4.00	3.94	3.90	3.84	3.81	3.77	3.76
167	4.19	4.08	4.01	3.96	3.91	3.86	3.83	3.79	3.78
168	4.21	4.10	4.03	3.97	3.93	3.88	3.85	3.81	3.80
169	4.22	4.11	4.04	3.99	3.95	3.90	3.87	3.83	3.84
170	4.24	4.13	4.06	4.00	3.97	3.92	3.89	3.85	3.83
171	4.26	4.15	4.08	4.02	3.99	3.94	3.91	3.88	3.87
172	4.27	4.17	4.10	4.05	4.01	3.96	3.94	3.91	3.90
173	4.29	4.19	4.12	4.07	4.04	3.99	3.98	3.91	3.95
174	4.31	4.21	4.14	4.10	4.08	4.04	4.03	3.98	
175	4.33	4.25	4.19	4.15	5.13	4.04	3.98		
176	4.36	4.25	4.22	4.20		4.10	4.03		
178	4.45	4.41							

TABLE V (Continued)

B Factors for PKP-BC

Δ	0	100	200	300	400	500	600	700	800
143								3.17	3.13
144								3.29	3.26
145						3.31	3.22	3.31	3.29
146		3.56	3.42	3.40	3.36	3.36	3.29	3.33	3.31
147	3.62	3.64	3.50	3.45	3.43	3.36	3.34	3.35	3.33
148	3.71	3.66	3.56	3.49	3.46	3.39	3.37	3.36	3.34
149	3.75	3.67	3.58	3.53	3.48	3.42	3.39	3.36	3.34
150	3.77	3.67	3.60	3.54	3.49	3.44	3.40	3.36	3.34
151	3.78	3.68	3.61	3.55	3.50	3.45	3.41	3.37	3.35
152	3.79	3.68	3.61	3.56	3.50	3.45	3.41	3.37	3.35
153	3.80	3.69	3.62	3.57	3.51	3.45	3.42	3.37	3.35
154	3.80	3.69	3.62	3.57	3.51	3.46	3.42	3.38	3.36
155	3.81	3.70	3.62	3.57	3.52	3.46	3.42	3.38	3.36
156	3.81	3.70	3.63	3.57	3.52	3.46	3.42	3.38	3.36
157	3.82	3.70	3.63	3.58	3.52	3.47	3.43	3.38	3.36

TABLE V (Continued)

B Factors for PKP-CD

Δ	0	100	200	300	400	500	600	700	800
110	4.13	4.02	3.94	3.89	4.84	3.78	3.74	3.69	3.68
111	4.13	4.02	3.95	3.89	3.84	3.78	3.74	3.69	3.68
112	4.13	4.02	3.95	3.89	3.84	3.78	3.74	3.69	3.68
113	4.13	4.03	3.95	3.89	3.84	3.78	3.74	3.69	3.68
114	4.14	4.03	3.95	3.89	3.84	3.79	3.75	3.70	3.68
115	4.14	4.03	3.95	3.90	3.85	3.79	3.75	3.70	3.68
116	4.14	4.03	3.96	3.90	3.85	3.79	3.75	3.70	3.69
117	4.14	4.03	3.96	3.90	3.85	3.79	3.75	3.70	3.69
118	4.14	4.03	3.96	3.90	3.85	3.79	3.75	3.70	3.69
119	4.14	4.03	3.96	3.90	3.85	3.79	3.75	3.70	3.69
120	4.15	4.04	3.96	3.91	3.86	3.80	3.76	3.71	3.69
121	4.15	4.04	3.97	3.91	3.86	3.80	3.76	3.71	3.70
122	4.15	4.04	3.97	3.91	3.86	3.80	3.76	3.71	3.70
123	4.15	4.04	3.97	3.91	3.86	3.80	3.76	3.72	3.70
124	4.16	4.05	3.97	3.92	3.86	3.81	3.77	3.72	3.70
126	4.16	4.05	3.98	3.92	3.87	3.81	3.77	3.72	3.71
127	4.16	4.05	3.98	3.92	3.87	3.81	3.77	3.73	3.71
128	4.17	4.06	3.98	3.92	3.87	3.82	3.78	3.73	3.71
129	4.17	4.06	3.99	3.93	3.88	3.82	3.78	3.73	3.72
130	4.17	4.06	3.99	3.93	3.88	3.82	3.78	3.73	3.72
131	4.17	4.06	3.99	3.93	3.88	3.82	3.79	3.74	3.72
132	4.18	4.07	3.99	3.94	3.89	3.83	3.79	3.74	3.73
133	4.18	4.07	4.00	3.94	3.89	3.83	3.79	3.74	3.73
134	4.18	4.07	4.00	3.94	3.89	3.84	3.80	3.75	3.73
135	4.19	4.08	4.00	3.95	3.90	3.84	3.80	3.75	3.74
136	4.19	4.08	4.01	3.95	3.90	3.84	3.80	3.75	3.74
137	4.19	4.08	4.01	3.95	3.90	3.85	3.81	3.76	3.74
138	4.20	4.09	4.01	3.96	3.91	3.85	3.81	3.76	3.75
139	4.20	4.09	4.02	3.96	3.91	3.85	3.81	3.77	3.75
140	4.21	4.09	4.02	3.97	3.91	3.86	3.82	3.77	3.76
141	4.21	4.10	4.03	3.97	3.92	3.86	3.82	3.78	3.76
142	4.22	4.10	4.03	3.97	3.92	3.87	3.83	3.78	3.77
143	4.22	4.11	4.04	3.98	3.93	3.87	3.83	3.79	3.77
144	4.23	4.11	4.04	3.99	3.93	3.88	3.84	3.79	3.78

TABLE V (Continued)

B Factors for PKP-CD

Δ	0	100	200	300	400	500	600	700	800
145	4.23	4.12	4.05	3.99	3.94	3.88	3.85	3.80	3.79
146	4.24	4.13	4.05	4.00	3.95	3.89	3.85	3.81	3.79
147	4.25	4.13	4.06	4.00	3.96	3.90	3.86	3.81	3.80
148	4.25	4.14	4.07	4.01	3.97	3.91	3.87	3.82	3.81
149	4.26	4.15	4.08	4.02	3.98	3.92	3.88	3.83	3.82
150	4.27	4.16	4.09	4.03	3.98	3.93	3.89	3.85	3.83
151	4.28	4.17	4.10	4.04	4.00	3.94	3.90	3.86	3.85
152	4.29	4.18	4.12	4.06	4.01	3.96	3.92	3.88	3.86
153	4.31	4.20	4.13	4.07	4.03	3.97	3.94	3.89	3.88
154	4.33	4.21	4.15	4.09	4.05	4.00	3.96	4.02	3.90
155	4.34	4.23	4.18	4.11	4.08	4.02	3.99	4.05	4.94
156	4.37	4.26	4.21	4.17	4.11	4.07	4.04		
157	4.43	4.33	4.28	4.23	4.17	4.12			
158	4.52	4.42	4.45	4.29	4.17				

TABLE V (Continued)

B Factors for PKP-DF

Δ	0	100	200	300	400	500	600	700	800
111	4.46	4.44	4.36	4.29	4.24	4.17	4.13	4.06	4.03
112	4.45	4.39	4.30	4.24	4.18	4.12	4.08	4.02	3.99
113	4.43	4.34	4.27	4.20	4.14	4.09	4.04	3.99	3.96
114	4.42	4.31	4.24	4.17	4.12	4.06	4.02	3.96	3.94
115	4.40	4.29	4.22	4.16	4.10	4.04	4.00	3.94	3.92
116	4.36	4.25	4.18	4.12	4.07	4.00	3.96	3.91	3.89
118	4.34	4.24	4.16	4.10	4.06	3.99	3.95	3.90	3.88
119	4.33	4.23	4.15	4.09	4.04	3.98	3.93	3.88	3.87
120	4.32	4.21	4.14	.408	4.03	3.97	3.92	3.87	3.86
121	4.30	4.20	4.13	4.07	4.01	3.96	3.91	3.86	3.85
122	4.29	4.19	4.12	4.06	4.00	3.95	3.90	3.85	3.84
123	4.28	4.18	4.11	4.05	3.99	3.94	3.89	3.84	3.83
124	4.27	4.17	4.10	4.04	3.98	3.93	3.88	3.83	3.82
125	4.26	4.16	4.09	4.03	3.98	4.92	3.88	3.83	3.81
126	4.25	4.15	4.08	4.02	3.97	3.91	3.87	3.82	3.80
127	4.24	4.14	4.07	4.01	3.96	3.90	3.86	3.81	3.79
128	4.24	4.14	4.07	4.01	3.95	3.89	3.86	3.80	3.79
129	4.23	4.13	4.06	4.00	3.95	3.89	3.85	3.80	3.78
130	4.22	4.13	4.05	3.99	3.94	3.88	3.84	3.79	3.77
131	4.22	4.12	4.04	3.99	3.94	3.88	3.83	3.78	3.77
132	4.21	4.11	4.04	3.98	3.93	3.87	3.83	3.78	3.76
133	4.21	4.11	4.03	3.97	3.92	3.86	3.82	3.77	3.76
134	4.20	4.10	4.02	3.97	3.92	3.85	3.81	3.77	3.75
135	4.19	4.10	4.02	3.96	3.91	3.85	3.81	3.76	3.75
136	4.19	4.09	4.01	3.96	3.91	3.84	3.80	3.76	3.74
137	4.18	4.09	4.01	3.95	3.90	3.84	3.80	3.75	3.74
138	4.18	4.08	4.00	3.95	3.90	3.83	3.79	3.75	3.73
139	4.17	4.07	4.00	3.94	3.89	3.83	3.79	3.74	3.73
140	4.17	4.07	3.99	3.94	3.89	3.83	3.79	3.74	3.72
141	4.17	4.07	3.99	3.93	3.88	3.82	3.78	3.73	3.72
142	4.16	4.06	3.99	3.93	3.88	3.82	3.78	3.73	3.71
143	4.16	4.06	3.98	3.92	3.87	3.81	3.77	3.72	3.70
144	4.15	4.05	3.97	3.91	3.86	3.80	3.76	3.71	3.70
145	4.14	4.04	3.97	3.91	3.86	3.80	3.76	3.70	3.69

TABLE V (Continued)

B Factors for PKP-DF

Δ	0	100	200	300	400	500	600	700	800
146	4.14	4.03	3.96	3.90	3.85	3.79	3.75	3.69	3.68
147	4.13	4.02	3.95	3.89	3.84	3.78	3.74	3.69	3.68
148	4.12	4.01	3.94	3.88	3.84	3.78	3.74	3.68	3.67
149	4.11	4.00	3.93	3.87	3.83	3.77	3.73	3.67	3.66
150	4.10	3.98	3.92	3.86	3.82	3.76	3.72	3.66	3.64
151	4.09	3.97	3.91	3.85	3.81	3.75	3.70	3.65	3.63
152	4.08	3.96	3.90	3.84	3.79	3.74	3.69	3.64	3.62
153	4.07	3.96	3.89	3.83	3.78	3.72	3.68	3.63	3.62
154	4.06	3.95	3.88	3.82	3.78	3.71	3.68	3.62	3.61
155	4.05	3.95	3.87	3.82	3.77	3.71	3.67	3.62	3.61
156	4.04	3.94	3.87	3.81	3.76	3.70	3.66	3.61	3.60
157	4.03	3.94	3.86	3.80	3.76	3.70	3.66	3.61	3.60
158	4.03	3.93	3.86	3.80	3.75	3.69	3.65	3.61	3.59
159	4.02	3.93	3.85	3.79	3.74	3.69	3.65	3.60	3.59
160	4.02	3.92	3.85	3.79	3.74	3.68	3.64	3.60	3.58
161	4.01	3.91	3.84	3.78	3.73	3.67	3.64	3.59	3.58
162	4.01	3.91	3.84	3.78	3.73	3.67	3.64	3.59	3.57
163	4.01	3.91	3.83	3.78	3.73	3.67	3.63	3.58	3.57
164	4.00	3.91	3.83	3.78	3.72	3.66	3.63	3.58	3.57
165	4.00	3.90	3.83	3.77	3.72	3.66	3.63	3.58	3.56
166	4.00	3.90	3.82	3.77	3.72	3.66	3.62	3.58	3.56
167	3.99	3.90	3.82	3.77	3.71	3.66	3.62	3.57	3.56
168	3.99	3.89	3.82	3.76	3.71	3.66	3.62	3.57	3.56
169	3.99	3.89	3.82	3.76	3.71	3.66	3.62	3.57	3.56
170	3.99	3.89	3.82	3.76	3.71	3.65	3.62	3.57	3.56
171	3.99	3.89	3.81	3.76	3.71	3.65	3.62	3.57	3.56
172	3.98	3.89	3.81	3.76	3.71	3.65	3.61	3.57	3.56
173	3.98	3.89	3.81	3.76	3.71	3.65	3.61	3.57	3.56
174	3.98	3.88	3.81	3.75	3.71	3.65	3.61	3.57	3.55
175	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.57	3.55
176	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.59	3.55
177	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.56	3.55
178	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.56	3.55
179	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.56	3.55
180	3.98	3.88	3.81	3.75	3.70	3.65	3.61	3.56	3.55

CONCLUSIONS

In this report we presented a set of PKP travel times and B factors computed with the Jordan and Anderson model B1. While arguments for the adequacy of the adopted earth model(s) are not in the scope of this report, the presentation of various tables and curves is novel and convenient for direct user application. The effort can be repeated in the future when better velocity and Q models become available.

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