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SAUDI ARABIAN PROJECT REPORT 261

SEISMICITY OF THE TIHAMAT-ASIR REGION, KINGDOM OF SAUDI ARABIA

by

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DIRECTORATE GENERAL OF MINERAL RESOURCES
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
JIDDAH, SAUDI ARABIA
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ABSTRACT

Knowledge of the seismicity of the west coast of Saudi Arabia is vitally important to the Kingdom. The eastern margin of the Red Sea, which includes all of the west coast of Saudi Arabia, is possibly cut by transform faults that may be capable of producing earthquakes large enough to cause damage in the heavily populated areas or in the industrial complexes under construction. Prior to this study, there were no seismic stations in Saudi Arabia and no studies of micro-earthquake activity. It was generally assumed that there were no active faults along the west coast. During the period 20 January to 22 February, 1978, five portable seismic stations were deployed in the Tihamat Asir in the southwest part of the country. A significant level of microearthquake activity was detected at a location that approximately coincides with the landward extension of the proposed transform fault. The recording of these earthquakes demonstrates that there are active faults at this location, probably associated with the currently active Red Sea tectonic system. The practical significance of these earthquakes cannot be evaluated from the

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few data available, and further studies should be undertaken to determine if there are significant seismic hazards along the west coast of Saudi Arabia.

INTRODUCTION

Uplift of the western margin of the Arabian Shield has been pronounced, with basement rocks reaching 2000-3000 m in elevation. This uplift, which is probably related in some way to the initiation and continued rifting in the Red Sea, is terminated on the west by a dramatic scarp, separating the highest elevations of uplift from elevations at most a few hundred meters along the coastal plain. The uplifted block slopes generally toward the northeast for about 500 km where the basement rocks disappear under the Paleozoic sediments that comprise the sedimentary basins in the eastern part of the country. The spreading of the Red Sea probably began in Late Oligocene time and has continued intermittently to the present. The sea opened to a width of about 400 km, possibly in two stages with the latest stage beginning about 5 m.y. ago. At the northern end of the Red Sea, the spreading is apparently terminated or greatly reduced by a transform fault running through the Gulf of Aqaba and the Dead Sea. Recent analyses of the aeromagnetic surveys in the Red Sea (Hall and others, 1977) have indicated a number of other transform faults that might be capable of producing significant seismic activity along the west coast of Saudi Arabia (fig. 1).

The eastern margin of the Red Sea and the associated coastal plain is an area of great importance to Saudi Arabia.

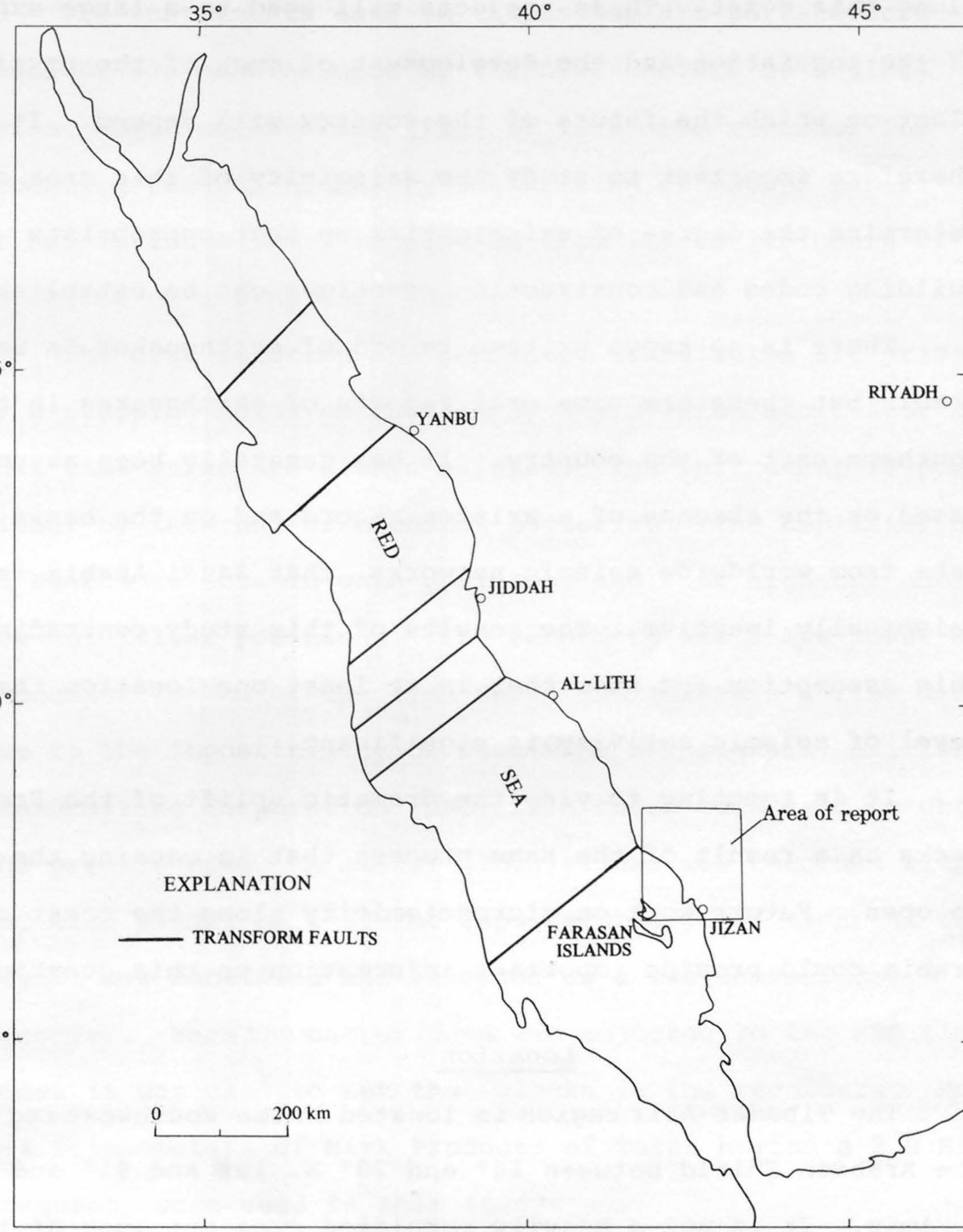

Figure 1. Index map of southwestern Saudi Arabia showing area of report and possible transform faults. Location of faults from Hall and others (1976).

Huge industrial and developmental projects are being constructed along this coast. These projects will lead to a large expansion of the population and the development of much of the physical plant on which the future of the country will depend. It is therefore important to study the seismicity of this area and determine the degree of seismic risk so that appropriate building codes and construction practices can be established.

There is no known written record of earthquakes in Saudi Arabia but there are some oral reports of earthquakes in the southern part of the country. It has generally been assumed, based on the absence of a written record and on the basis of data from worldwide seismic networks, that Saudi Arabia is seismically inactive. The results of this study contradict this assumption and show that in at least one location the level of seismic activity is significant.

It is tempting to view the dramatic uplift of the Precambrian rocks as a result of the same process that is causing the Red Sea to open. Future work on microseismicity along the coast of Saudi Arabia could provide important information on this question.

Location

The Tihamat-Asir region is located in the southwest region of the Arabian Shield between 16° and 20° N. lat and 41° and 43° E. long. It is not a heavily populated area but much of the area is cultivated. Most of the towns are easily accessible by means of blacktop paved roads.

Instrumentation

The instruments used in this study are portacorders Model RV-320 manufactured by TELEDYNE-GEOTECH of Dallas, Texas. Each portacorder (fig. 2) is a drum recorder for producing records either by ink writing or smoked paper. It has variable speed to provide from 3.5 to 115 hours of recording on a single record.

The drum rotation and pen motor translation are driven by a stepping motor controlled by a precision oscillator so that time marks are always aligned. The instrument is powered either by internal or external batteries. The amplifier has 12 switch selectable gain positions and four high-cut and three low-cut filter positions. The recorders use a low-power microprocessor to control the time marks and generate a time display. Due to the impossibility of receiving WWV signals, British Broadcasting Corporation (BBC) time codes were used to obtain the precise time. A master-clock signal was recorded with the BBC time signal on a stereo tape recorder, and then the tape signal was rectified and recorded on a two-channel chart recorder. When the master clock was adjusted to the BBC time codes it was used to set the clocks in the recorders. Model L-4 seismometers of Mark Products of Texas having a 2.0 Hz frequency were used in this study.

Acknowledgements

The author is grateful to J.H. Healy, Office of Earthquake Studies, U.S. Geological Survey (USGS), Menlo Park, for his

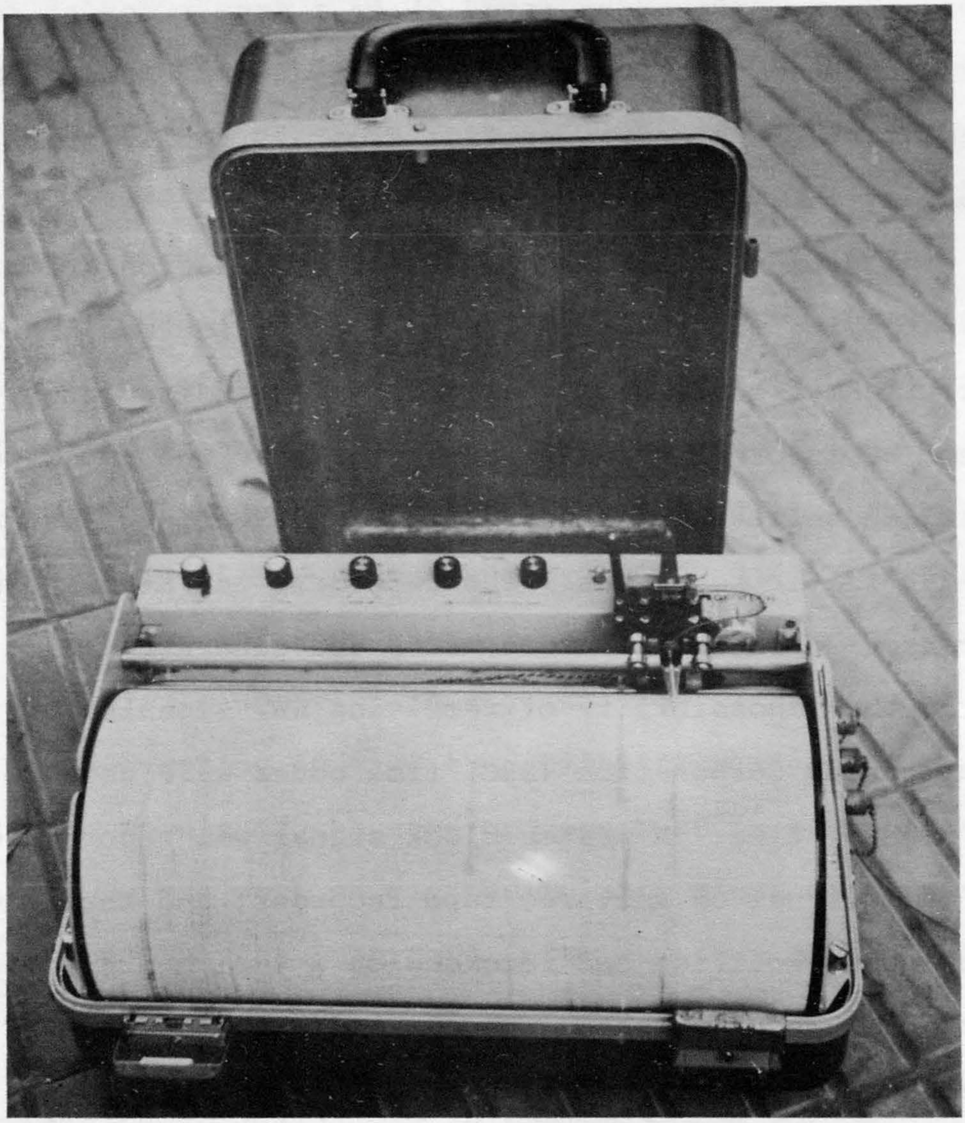

Figure 2. Portacorder Model RV-320.

assistance and to W. Jackson and Steve Gallanthine, also of the USGS, for their advice on the field operation and maintenance of recorders. This work could not have been completed without the cooperation of the field crew.

DATA AND RESULTS

During January and February 1978 a seismic refraction profile, extending for about 1000 km from the Farasan Islands in the Red Sea to a point near Riyadh (fig. 1), was recorded. The work was done by a group from the United States Geological Survey.

Five portacorders were deployed to monitor the shots and search for seismic activity in the Tihamat Asir area. The portacorders were deployed at 17 locations (table 1 and fig. 3), and earthquakes were recorded at 15 of the recording sites. The instrument locations were selected to provide data on the suspected transition from oceanic to continental crust, but the high level of local seismicity was not anticipated and the station distribution was not designed for optimum recording of local seismicity. However, each of 14 earthquakes were recorded on three or more stations, and fairly accurate locations were calculated for these events (table 2 and fig. 4). A total of 72 earthquakes were detected during 33 days of recording (appendix). Constant P and S velocities were used in calculating the epicentral distances given in the appendix.

The earthquakes were located by means of the USGS computer in Menlo Park using the USGS program Hypo-71 (Lee and others, 1975). Both P and S readings were used for the locations.

Table 1.--*Latitude and longitude of seismic recording stations, Tihamat-Asir region, Kingdom of Saudi Arabia*

Station number	Name	North latitude	East longitude
1	Old Camp	17°49'32"	42°17'26"
2	Schist Base	17 50 38	42 22 34
3	White Quartz	17 45 08	42 21 08
4	Shot Point 5	17 43 29	42 20 52
5	Air Strip	17 42 07	42 18 00
6	Camel Bush	17 43 13	42 09 43
7	Deer Track	17 42 07	42 05 26
8	Wadi Baydh	17 34 57	42 18 00
9	Wadi Jowan	17 37 43	42 28 17
10	Al Hago	17 29 27	42 42 00
11	Wadi Shadhan	17 25 52	42 44 00
12	Masliah	17 24 46	42 37 26
13	Mahlan	17 20 38	42 37 26
14	Ardah	17 03 35	43 01 25
15	Jizan Dam	17 02 45	42 27 10
16	Abu Arish Camp	16 28 54	42 26 02
17	Abu Arish Road	16 26 42	42 22 05

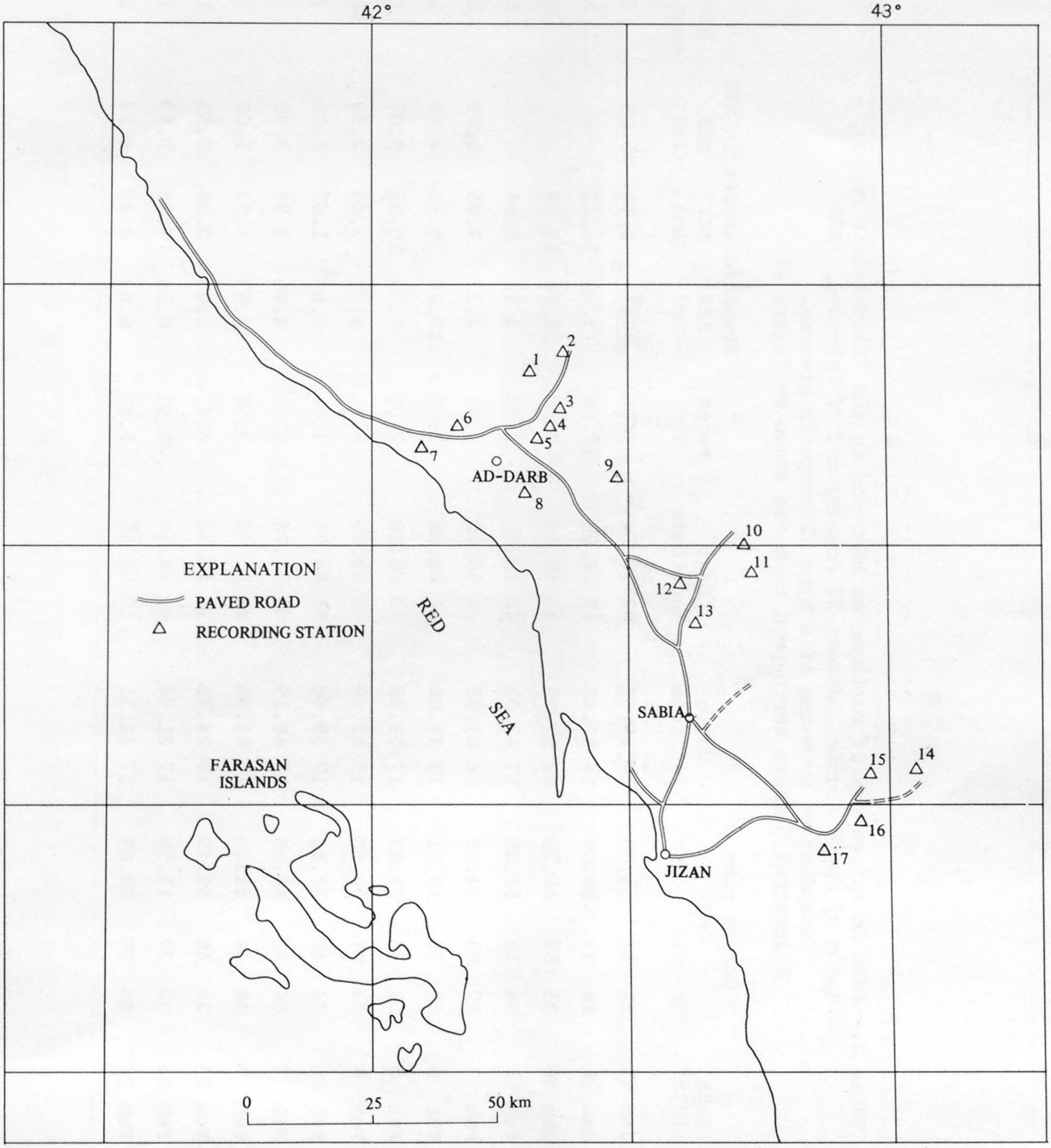

Figure 3. Locations of seismic recording stations, Tihamat Asir region, Kingdom of Saudi Arabia.

Table 2.--*Data on epicenters of earthquakes recorded in the Tihamat-Asir region, Kingdom of Saudi Arabia, between 23 January and 16 February, 1978*
[Compilation by means of a Hypo 71 computer program.
Epicentral numbers correspond to those shown on figure 4]

Epicenter number	Date (1978)	Origin time GMT hr	min	sec	North latitude	East longitude	Depth (km)	Standard errors in XYZ ERX (km)	ERY (km)	ERZ (km)	Richter magnitude
1	Jan 23	22	33	54.09	18°16.63'	42°12.38'	2.00	36.1	2.91	31.28	2.43
2	Jan 25	18	37	54.09	17 53.45	41 22.99	17.26	3.98	34.42	---	2.50
3	Jan 30	05	55	48.76	18 01.99	42 30.14	2.00	28.44	23.92		2.08
4	Feb 3	04	12	56.48	17 43.05	42 12.03	2.00	2.12	0.64		1.37
5	Feb 3	17	55	34.60	18 01.88	41 56.45	4.31	2.32	7.85	5.89	2.35
6	Feb 5	03	33	18.01	17 37.06	41 48.98	2.00	17.05	5.55	4.99	1.86
7	Feb 5	03	36	19.83	17 59.48	42 06.20	2.00	1.55	10.98	6.07	1.98
8	Feb 5	03	37	29.60	17 42.69	41 49.29	6.41	4.47	2.64	2.58	2.36
9	Feb 5	04	40	37.53	17 39.60	41 49.34	4.14	3.69	1.67	1.00	2.24
10	Feb 5	04	43	44.30	17 48.19	41 52.26	6.62	4.95	4.95	3.98	2.73
11	Feb 5	04	44	51.26	17 45.66	41 50.03	3.97	3.57	1.83	1.02	1.83
12	Feb 13	21	48	59.49	17 24.70	42 44.78	6.91	0.65	0.96	0.53	1.86
13	Feb 16	00	37	13.56	17 21.94	42 44.78	20.91	8.84	9.18	9.83	1.53
14	Feb 16	06	08	09.09	17 41.31	43 02.05	5.92	6.63	8.40	6.54	2.40

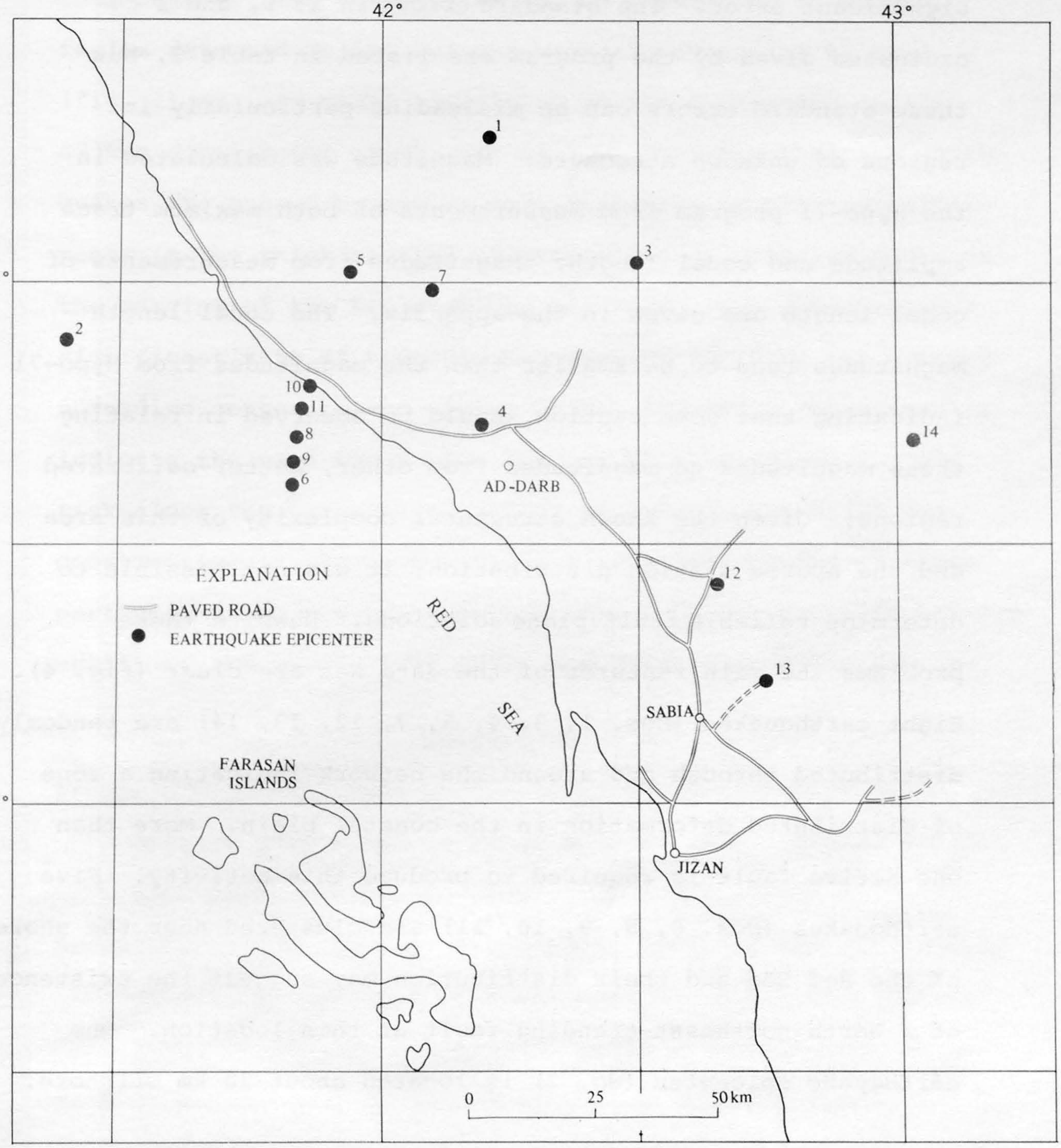

Figure 4. Locations of epicenters of earthquakes recorded in Tihamat Asir region, Kingdom of Saudi Arabia, between 23 January and 16 February, 1978. See table 2.

Location of an earthquake outside a local network can have significant error. The standard errors in X, Y, and Z coordinates given by the program are listed in table 2, but these standard errors can be misleading particularly in regions of unknown structure. Magnitude was calculated in the Hypo-71 program from measurements of both maximum trace amplitude and codal length. Magnitudes from measurements of codal length are given in the appendix. The codal length magnitudes tend to be smaller than the magnitudes from Hypo-71 indicating that some caution should be observed in relating these magnitudes to magnitudes from other, better-calibrated regions. Given the known structural complexity of this area and the sparse station distribution, it was not possible to determine reliable fault-plane solutions. Despite these problems the main features of the data set are clear (fig. 4). Eight earthquakes (Nos. 1, 3, 4, 5, 7, 12, 13, 14) are randomly distributed through and around the network indicating a zone of distributed deformation in the coastal plain. More than one active fault is required to produce this activity. Five earthquakes (Nos. 6, 8, 9, 10, 11) are clustered near the shore of the Red Sea and their distribution may suggest the existence of a north-northeast-trending fault at this location. One earthquake epicenter (No. 2) is located about 30 km offshore.

DISCUSSION

The level of seismic activity in the study area is surprisingly high for a supposedly inactive region. The activity forces a re-evaluation of our thinking about the stability of this region. The earthquakes may be related to transform faults detected in the Red Sea magnetic anomalies by Hall (fig. 1) or they might be related to the continuing uplift of the continental crust. It is also possible that the earthquakes are caused by active salt diapirism or related adjustments in the thick section of evaporites and clastic rocks on the margins of the Red Sea. In any case, they demonstrate a significant rate of tectonic deformation far from the current spreading center in the center of the Red Sea. These results indicate the need for a more careful analysis of earthquake risk along the coast particularly at sites where major new construction is proposed. Further detailed studies of these earthquakes may provide important clues to the relation between uplift of the continental crust and spreading of the Red Sea.

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APPENDIX

Earthquakes recorded between 20 January and 20 February 1978,
in the Tihamat-Asir region, Kingdom of Saudi Arabia
[Magnitude is computed from codal length. Stations
listed on table 1 and shown on figure 3.]

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
1	Jan 20	1	03	48	53.5	1.8	14.72		P	20	1.4
2	Jan 21	5	16	39	31	2.0	16.34	P		50	2.4
3	Jan 21	5	21	18	25	2.2	18	P		10	1.0
4	Jan 23	5	22	34	05.8	8.5	69.53	P		30	1.7
	Jan 23	4	22	34	05.8	8.5	69.5	P		15	2.2
	Jan 23	6	22	34	05.5	9.0	73.62	P		5	2.0
5	Jan 23	5	23	55	12.8	2.5	20.5		P	5	0.7
6	Jan 25	7	18	38	06	9.0	73.62		P	40	2.1
6	Jan 25	4	18	38	09	12	98.16			40	2.1
6	Jan 25	3	18	38	09	12	98.16		P	45	2.2
7	Jan 26	5	14	06	02	2	16.38	P		40	2.1
8	Jan 26	3	15	29	51	3	24.54	P		15	1.0
9	Jan 26	3	21	08	54.5	18	147.24	P		50	2.4
10	Jan 27	3	12	38	27	4	32.72	P		30	1.7
11	Jan 27	3	12	41	05	4.5	36.8	P		35	2.0
12	Jan 27	7	07	47	11	4.5	36.8	P		30	1.7
12	Jan 27	5	07	47	11	5.0	40.9	P		40	2.1
13	Jan 27	7	12	19	27.5	4.5	36.8		P	25	1.6
13	Jan 27	5	12	19	28.5	4.0	32.72	P		30	1.7

Appendix. Earthquakes recorded in the Tihamat-Asir region (cont.)

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
14	Jan 27	5	12	22	06	5.0	40.9		P	20	1.4
15	Jan 27	5	15	27	15	7.0	57.26	P		40	2.1
16	Jan 27	5	17	28	26.5	4.0	32.72	P		35	2.0
16	Jan 27	4	17	28	56	4.0	32.72	P		45	2.2
17	Jan 28	4	09	06	23	3.0	24.54	P		10	1.0
18	Jan 28	4	10	07	00	1.0	8.18	P		10	1.0
19	Jan 28	4	18	10	23	11.0	89.98	P		25	1.5
20	Jan 28	4	09	52	03	7.0	57.26	P		65	2.7
21	Jan 28	5	13	39	52	3.0	24.54	P		30	1.7
22	Jan 30	5	05	56	05	4.0	32.73	P		10	1.0
22	Jan 30	4	05	55	55	4.5	36.81	P		28	1.7
22	Jan 30	3	05	55	52.5	4.5	32.73	P		25	1.5
23	Jan 30	3	07	27	38	0	0	P		2	0.3
24	Jan 31	3	06	08	28	15	122.7	P		40	2.1
24	Jan 31	5	06	08	29	0	0	P		30	1.7
25	Feb 1	2	05	33	31.5	4.0	32.72	P		35	2.0
26	Feb 1	2	10	29	04	2.0	16.36	P		20	1.4
27	Feb 1	5	05	49	24	2.0	16.36	P		25	1.5
28	Feb 3	2	04	13	1.5	3.0	24.54	P		12	1.1
28	Feb 3	5	04	12	58.5	2.0	16.56	P		13	1.11
28	Feb 3	7	04	12	59	1.5	12.27	P		8	0.9
29	Feb 3	8	12	40	24	3.0	24.54	P		15	1.2
29	Feb 3	9	12	40	29	1.0	8.18	P		10	1.0
30	Feb 3	9	17	55	47	9.5	77.71	P		30	1.7
30	Feb 3	7	17	55	42	7	57.26	P		35	2.0

Appendix. Earthquakes recorded in the Tihamat-Asir region (cont.)

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
30	Feb 3	8	17	55	46	8.8	71.98	P		40	2.1
30	Feb 3	2	17	55	44.5	7.0	57.26	P		55	2.5
31	Feb 5	9	03	28	28	0	0	P		3	0.4
32	Feb 5	9	03	29	08	1.5	12.27	P		5	0.7
33	Feb 5	9	03	30	33	10	81.8	P		20	1.4
33	Feb 5	8	03	30	29	10	81.8	P		25	1.5
34	Feb 5	8	03	30	19	2	16.36	P		5	0.5
35	Feb 5	9	03	33	40	0	0	P		4	0.6
35	Feb 5	7	03	33	24	5	40.9		P	20	1.4
35	Feb 5	8	03	33	28	8	65.44	P		15	1.2
36	Feb 5	8	03	35	53	8	65.44	P		15	1.2
36	Feb 5	9	03	36	04	0	0	P		2	0.3
37	Feb 5	9	03	36	41	0	0	P		10	1.0
37	Feb 5	7	03	36	26.5	4.5	36.81	P		35	2.0
37	Feb 5	8	03	36	30	8	65.44	P		40	2.1
38	Feb 5	9	03	36	51	0	0	P		5	0.5
39	Feb 5	9	03	36	57	0	0	P		4	0.4
40	Feb 5	9	03	37	41.5	9	73.62	P		45	2.2
40	Feb 5	7	03	37	35.5	4.5	36.81	P		40	2.1
40	Feb 5	8	03	37	39	8	65.44	P		40	2.1
40	Feb 5	2	03	37	41	8	65.44	P		40	2.1
41	Feb 4	2	01	56	12	0	0	P		2	0.3
42	Feb 4	2	17	50	33	2	16.36	P		20	1.4
43	Feb 5	2	03	32	24.5	2	16.36	P		15	1.2

Appendix. Earthquakes recorded in the Tihamat-Asir region (cont.)

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
43	Feb 5	9	03	38	26.5	0	0	P		5	0.5
44	Feb 5	9	03	38	50	0	0	P		2	0.3
45	Feb 5	7	03	39	57	0	0	P		15	1.2
45	Feb 5	7	03	39	56	8	65.44	P		17	1.2
46	Feb 5	9	03	46	07	0.5	4.09	P		6	0.65
47	Feb 5	9	03	41	07.5	0	0	P		3	0.3
47	Feb 5	8	03	40	56	8	65.44	P		15	1.2
48	Feb 5	8	03	34	12	8	65.44			15	1.2
49	Feb 5	9	04	40	49	9	73.62		P	30	1.7
49	Feb 5	7	04	40	43.5	4	32.72	P		35	2.0
49	Feb 5	8	04	40	47	8	65.44	P		40	2.1
49	Feb 5	2	04	40	49	8	65.44	P		40	2.1
50	Feb 5	9	04	4	23	0	0	P		3	0.3
51	Feb 5	9	04	43	56	9	73.62		P	50	2.4
51	Feb 5	7	04	43	49.5	4	32.72	P		35	2.0
51	Feb 5	8	04	43	53.5	7.5	61.35	P		60	2.6
51	Feb 5	2	04	43	55	6.5	53.17	P		50	2.4
52	Feb 5	8	04	44	0.5	8	65.44		P	30	1.7
53	Feb 5	7	04	44	57	4	32.72			20	1.4
53	Feb 5	9	04	45	03.5	9	73.62		P	20	1.4
53	Feb 5	2	14	45	02	8	65.44	P		40	2.1
54	Feb 5	7	04	46	03	4	32.72			10	1.0
54	Feb 5	8	04	46	07	7.5	61.35	P		12	1.1
55	Feb 5	9	04	46	17.5	13	106.34	P		25	1.6
55	Feb 5	7	04	46	16.5	4.5	36.81	P		20	1.4

Appendix. Earthquakes recorded in the Tihamat-Asir region (cont.)

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
55	Feb 5	8	04	46	20	8	65.44	P		15	1.2
55	Feb 5	2	04	46	17	14	114.52			40	2.1
56	Feb 5	9	04	49	40	3	24.54				
56	Feb 5	8	04	49	29	8	65.44		P	15	1.2
57	Feb 13	5	21	49	09	7	57.26	P		30	1.7
57	Feb 13	13	21	49	01	1	8.18	P		25	1.6
57	Feb 13	12	21	49	01	1	8.18	P		35	2.0
57	Feb 13	10	21	49	01.5	2	16.36	P		30	1.7
58	Feb 14	13	01	15	57	12	98.16		P	25	1.6
58	Feb 14	12	01	15	57	12	98.16		P	35	2.0
58	Feb 14	10	01	15	57.5	11	89.98	P		30	1.7
59	Feb 15	11	22	20	39.5	1.2	9.82	P		3	0.3
60	Feb 15	11	22	21	36.5	1.0	8.18	P		35	0.4
61	Feb 15	11	23	16	23	1.5	12.27		P	5	0.5
62	Feb 16	11	00	37	18	2.0	16.36		P	25	1.6
62	Feb 16	13	00	37	18	2	16.36	P		12	1.1
62	Feb 16	10	00	37	17.8	2	16.36	P		12	1.1
62	Feb 16	12	00	37	18	2	16.36	P		15	1.2
63	Feb 16	12	06	08	19.0	4.0	32.72			45	2.2
63	Feb 16	13	06	08	19.5	6.0	49.08	P		40	2.1
63	Feb 16	10	06	08	17.5	7.5	61.35		P	30	1.7
63	Feb 16	11	06	08	18	1.5	12.77	P		5	0.5
64	Feb 16	10	03	48	18	0	0	P		15	1.2
65	Feb 16	13	07	42	18.5	11	89.98	P		30	1.7

Appendix. Earthquakes recorded in the Tihamat-Asir region (cont.)

Event	Date (1978)	Station	P-arrival GMT hr	min	sec	S-P sec	Distance (km)	P-motion Up	Down	Duration sec	Magnitude (Richter Scale)
66	Feb 19	15	22	54	31	5	40.9	P		20	1.4
67	Feb 19	15	22	56	55	5	40.9	P		20	1.4
68	Feb 19	14	23	27	40	6	49.08	P		30	1.7
69	Feb 20	14	01	00	17.5	14	114.32	P		75	2.75
69	Feb 20	15	01	00	16	13	106.34	P		55	2.5
70	Feb 20	15	07	50	37	6	49.08	P		50	2.4
71	Feb 20	14	08	00	09	6	49.08	P		30	1.7
72	Feb 20	14	07	54	10	6	49.08	P		20	1.4

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