28. *Investigation on the Deformation of the Earth's Crust in the Tango District connected with the Tango Earthquake of 1927. (Part 4.)*

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In his previous papers[1] published in this Bulletin, the writer discussed the deformation of the earth's crust in the Tango district that was caused by the Tango destructive earthquake of 1927. For the discussions given in these papers were used as data the results of the precise levellings and secondary triangulations in the district which the Land Survey Department of the Imperial Army has repeatedly made after the earthquake. Recently the same Department[2] has moreover accomplished an extensive revision of the third order triangulation over the same district, of which the results were kindly placed at our disposal. The third order triangulation points occupied by the survey amount to 226 in number. The new results of the triangulation were compared with the older ones obtained some 30 years ago. For the purpose of comparing the old and new geodetic coordinates of the triangulation points, it is necessary to make some assumption regarding which one of the sides of the geodetic triangles in the district is to be taken as remained unchanged both in its length and azimuth notwithstanding the disturbance of the earthquake. This side must be one of a geodetic trigangle of which the change in shape between the old and new surveys is smallest of all in the district. Among all the primary triangles in the district, the sum of the absolute values of the differences of internal angles between the old and new surveys is smallest for the triangle Hyônoyama, Kasagatayama and Tokonooyama, being 0″298. Among the triangles that are in contact with the above one, the sum of the absolute values of the differences of internal angles between the old and new surveys is smallest for the triangle Hyônoyama, Kasagatayama and Sirahatayama, being 1″924. Being com-

1) C. TSUBOI, *Bull. Earthq. Res. Inst.*, 6 (1929), 71; 8 (1930), 153, 388; 9 (1931), 423.

2) LAND SURVEY DEPARTMENT, "Results of the Revision of the Third Order Triangulations in the Tango District," (1930), (a pamphlet in Japanese).

mon to both triangles, the side Hyônoyama-Kasagatayama was taken to have been unchanged between the old and new surveys both in its length and azimuth. This assumption is of course a tentative one, but so far as we confine ourselves to the discussions of the relative displacements of the triangulation points and of the strain of the earth's crust produced by them, this assumption, though it may differ a little from reality, will produce no serious errors in the discussions besed on it. The horizontal and vertical displacements of the triangulation points as found by the comparison of the old and new surveys in this way are given in Table I, Fig. 1 and Fig. 2. Though these values have already been published in pamphlets by the Land Survey Department in Japanese lánguage, the writer may be allowed to reproduce the values here for the benefit of reference.

Table I.

A. Horizontal and Vertical Displacements of the First Order Triangulation Points in the Tango District.

u Eastward Displacement.
v Northward Displacement.
w Upward Displacement.
$\sqrt{u^2+v^2}$ Resultant Horizontal Displacement.
$tg^{-1}\frac{u}{v}$ Azimuth of Horizontal Displacement Measured Clockwise from North.

Taiangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Taikoyama	−0·473	+0·339	0·582	305° 38′	+0·04
Kuruhizan	+0·106	−0·197	0·224	151 43	−0·16
Isanagosan	+0·018	−0·484	0·484	177 52	+0·02
Taneziyama	−0·204	+0·259	0·330	321 46	−0·16
Tokonooyama	−0·033	−0·006	0·033	259 42	0·00
Karasugadake	−0·088	+0·169	0·190	332 30	+0·03

B. Horizontal and Vertical Displacements of the Second Order Triangulation Points in the Tango District.

u Eastward Displacement.
v Northward Displacement.
w Upward Displacement.
$\sqrt{u^2+v^2}$ Resultant Horizontal Displacement.
$tg^{-1}\frac{u}{v}$ Azimuth of Horizontal Displacement Measured Clockwise from North.

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Kwannonzan	−0·023	−0·068	0·072	198° 41′	+0·05
Minato	+0·078	−0·364	0·372	167 54	−0·31
Nyoô	−0·070	−0·807	0·810	184 57	+0·16
Motomiduka	−0·083	−0·151	0·172	208 48	+0·05
Mitani	+0·126	−0·308	0·333	157 45	−0·15
Ooyama	−0·139	+0·243	0·280	330 14	−0·23
Simomura	+0·015	−0·182	0·183	175 17	+0·11
Hatidyômura	+0·003	−0·247	0·247	179 18	−0·08
Ôokadera	−0·136	−0·277	0·309	206 9	−0·01
Isikawamura.	−0·408	+0·425	0·589	316 10	−0·02
Yuragadake	−0·393	+0·295	0·492	306 59	−0·13
Sengenzi	−0·219	+0·265	0·344	320 26	−0·05
Kayaoku	−0·151	−0·009	0·151	266 35	+0·06
Higasimitumatumura	−0·035	+0·243	0·245	351 48	−0·13
Hurudera	+0·066	−0·169	0·182	158 40	+0·06
Amautimura	−0·242	+0·136	0·278	299 20	−0·03
Izamura	+0·020	−0·151	0·152	172 27	+0·10
Sendyôgadake	−0·182	+0·253	0·312	324 16	−0·15
Okadanakamura	−0·272	+0·320	0·420	319 38	+0·15
Yôrôgadake	−0·116	+0·154	0·193	323 1	−0·02
Yabegadake	−0·124	+0·317	0·340	338 38	−0·17
Noboriotôge	−0·124	+0·043	0·131	289 8	−0·17
Kutami	−0·101	+0·210	0·233	334 19	−0·04
Mutuyori	−0·111	+0·154	0·190	324 13	+0·08
Nômi	−0·045	+0·037	0·058	309 26	−0·11
Higasihattamura	−0·048	+0·136	0·144	340 34	+0·17
Hosibara	−0·066	+0·126	0·142	332 21	+0·01
Kamikawagutimura	−0·157	+0·065	0·170	292 29	−0·11

(*to be continued.*)

Table I. B. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Kamanowa	+0·015	+0·049	0·051	17° 1′	+0·02
Oda	- 0·056	+0·037	0·067	303 27	+0·27
Kamikawai	+0·013	+0·040	0·042	18 0	−0·18
Simotakeda	−0·094	+0·031	0·099	288 15	+0·02
Nomura	−0·432	+0·376	0·573	311 2	−0·03
Itigao	−0·869	+0·626	1·071	305 46	−0·08
Oohara	−0·588	+0·327	0·673	299 5	−0·17
Simooka	+0·531	−1·128	1·247	154 48	−0·08
Yorizawa	−0·745	+0·804	1·096	317 11	−0·09
Tudumigadake	−0·524	+0·524	0·741	315 0	0·24
Kurosaki	−0·556	+0·487	0·739	311 13	+0·03
Miemura	+0·116	+0·918	0·925	7 12	+0·48
Osima	−0·287	+0·404	0·496	324 37	−0·22

C. Horizontal and Vertical Displacements of the Third Order Triangulation Points in the Tango District.

u Eastward Displacement.
v Northward Displacement.
w Upward Displacement.
$\sqrt{u^2+v^2}$ Resultant Horizontal Displacement.
$tg^{-1}\frac{u}{v}$ Azimuth of Horizontal Displacement Measured Clockwise from North.

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Kumi	−0·0	−0·277	0·277	180° 00′	−0·08
Kôyama	−0 126	−0·493	0·509	194 20	+0·10
Hakoisi	—	—	—	—	—
Oomukai	+0 050	−0·431	0·434	173 23	−0·20
Kandani	+0·126	−0·277	0·304	155 32	−0·32
Totitani	+0·202	−0·370	0·422	151 22	−0·02
Urake	+0·025	−0·647	0·647	177 47	+0 03
Hasidume	+0·101	−0·493	0·503	168 25	−0·02
Idusumi	+0·101	−0·431	0·443	166 49	−0·18
Suda	+0·202	−0·277	0·343	143 54	−0·09

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Itinono	+0·176	−0·431	0·466	157° 47′	−0·16
Sano	+0·126	−0·678	0·690	169 28	+0·19
Nonaka	+0·101	−0·555	0·564	169 41	−0·09
Hutamata	0·000	−0·431	0·431	180 0	−0·13
Arikuma	−0·252	+0·185	0·313	306 17	+0·08
Dannosaka	−0·202	0·000	0·202	270 0	+0·01
Ooeyama	−0·252	+0·339	0·422	323 22	−0·11
Akaisidake	−0·126	+0·247	0·277	332 58	−0·06
Hukôtôge	−0·202	+0·431	0·476	334 53	−0·18
Odamura	−0·277	+0·462	0·539	329 3	−0·08
Iwaya	−0·176	−0·185	0·255	223 34	−0·40
Kanawaridani	−0·504	+0·462	0·684	312 31	−0·02
Tyûda	−0·252	+0·308	0·398	320 43	−0·28
Waki	−0·428	+0·308	0·527	305 44	−0·06
Okuyama	−0·403	+0·370	0·547	312 33	+0·01
Nohara	−0·101	+0·308	0·324	341 51	−0·22
Kannonzi	−0·202	+0·247	0·319	320 43	−0·17
Kawabehara	−0·176	+0·247	0·303	324 32	−0·39
Kuroti	0·0	+0·370	0·370	0 0	−0·24
Uranyûhinata	−0·302	−0·185	0·354	238 31	—
Usiroyama	−0·328	+0·031	0·330	275 24	−0·08
Hukayûo	−0·151	+0·123	0·195	309 10	—
Miyama	−0·151	+0·154	0·216	315 34	−0·02
Usitani	−0·176	+0·154	0·234	311 11	+0·11
Sugiyama	−0·176	+0·186	0·255	316 26	−0·21
Hukuroya	−0·176	+0·123	0·215	304 57	−0·06
Toisigatake	−0·126	+0·370	0·391	341 12	−0·24
Kyôhaku	−0·278	+0·247	0·372	311 37	−0·15
Dinusi	−0·353	+0·277	0·449	308 7	+0·11
Seikôzi	−0·302	+0·308	0·431	315 34	+0·10
Ononai	−0·252	+0·216	0·332	310 36	+0·15
Nakati	−0·202	+0·247	0·319	320 43	−0·03
Kuretani	−0·176	+0·216	0·279	320 50	+0·27
Togura	−0·076	+0·247	0·258	342 54	0·0

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Huruike	−0·126	+0·185	0·224	325° 45′	−0·15
Dake	+0·126	+0·308	0·333	22 15	−0·11
Yuhune	−0·050	+0·431	0·434	353 23	−0·24
Sôgômura	−0·076	+0·401	0·408	349 16	−0·18
Kômori	−0·126	+0·216	0·250	329 45	+0·05
Tunedu	−0·076	+0·092	0·120	320 26	+0·06
Hiuragatake	−0·101	+0·308	0·324	351 51	−0·23
Sorayama	−0·076	+0·431	0·438	350 0	−0·25
Hamagasira	−0·328	+0·247	0·411	306 59	—
Miyatani	−0·252	+0·185	0·313	306 17	−0·02
Kitisaka	−0·176	+0·247	0·303	324 32	0·0
Kahara	−0·176	+0·154	0·234	311 11	−0·02
Rokudi	−0·227	+0·154	0·274	304 9	+0·04
Iidumi	−0·176	+0·062	0·186	289 24	−0·01
Aodi	−0·176	+0·123	0·215	304 57	−0·06
Hazaki	−0·227	+0·185	0·293	309 10	−0·01
Takabatake	−0·202	+0·185	0·274	312 29	+0·06
Tendai	−0·252	+0·185	0·313	306 17	+0·01
Sengokuzan	−0·252	+0·154	0·295	301 26	+0·02
Nakatakidaki	−0·101	+0·154	0·182	326 44	+0·04
Zyosi	+0·076	+0·185	0·200	22 20	+0·01
Mizono	−0·075	−0·863	0·866	184 58	+0·17
Kidu	−0·101	−1·048	1·053	185 30	+0·20
Tukinami	+0·025	−1·202	1·202	178 49	+0·18
Egasayama	−0·101	+0·092	0·137	312 20	+0·11
Kôsindani	−0·101	+0·123	0·159	320 37	−0·18
Horikiri	−0·101	+0·185	0·211	331 22	−0·03
Kurio	−0·076	−0·031	0·082	247 49	−0·10
Tawa	−0·076	+0·154	0·172	333 44	−0·12
Hata	−0·126	−0·123	0·176	225 41	−0·10
Nagasako	−0·152	+0·031	0·155	281 32	−0·17
Umedani	−0·152	+0·062	0·164	292 11	−0·09
Mitakeyama	−0·202	+0·092	0·222	294 29	−0·18
Itinomiya	−0·101	−0·154	0.184	213 16	−0·14

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Tatunozyô	−0·076	−0·062	0·098	230° 48′	−0·05
Himegami	−0·025	+0·123	0·125	348 31	−0·18
Okiyama	−0·126	+0·185	0·224	325 45	−0·12
Siroyama	—	—	—	—	—
Hadumaki	−0·202	+0·062	0·211	287 04	−0·13
Simoamadu	−0·227	+0·154	0·274	304 09	−0·11
Kôrinzi	−0·076	+0·185	0·200	337 40	−0·12
Nagayama	−0·126	+0·062	0·140	296 12	−0·22
Nagau	−0·328	0·0	0·328	270 0	−0·11
Kasadani	−0·101	+0·247	0·267	337 46	+0·03
Tengamine	−0·101	+0·216	0·239	334 56	+0·08
Bessyo	−0·101	+0·216	0·239	334 56	−0·12
Sorayama	−0·076	+0·185	0·200	337 40	−0·07
Takadake	−0·152	+0·092	0·178	301 11	−0·10
Sigazato	−0·076	+0·154	0·172	333 44	+0·07
Ootani	+0·025	+0·123	0·125	11 29	−0·05
Okuyama	−0·051	+0·216	0·222	346 43	+0·13
Motomiya	−0·025	+0·154	0·156	350 47	−0·21
Sutizan	0·0	+0·062	0·062	0 0	−0·11
Takasiro	−0·051	+0·123	0·133	337 29	−0·16
Kisaiti	−0·202	+0·123	0·236	301 20	−0·11
Monobe	−0·101	+0·123	0·159	320 37	−0·02
Mikunizan	−0·101	+0·185	0·211	331 22	+0·02
Miseuzan	0·0	+0·123	0·123	0 0	+0·10
Kurotani	−0·126	+0·123	0·176	314 19	0·0
Uesugi	−0·076	+0·062	0·098	309 12	+0·03
Nakamurayama	−0·051	+0·092	0·106	331 0	−0·06
Nanahyakkoku	−0·025	+0·154	0·156	350 47	+0·06
Arigaduku	+0·202	+0·277	0·343	36 6	+0·10
Itibandani	0·0	+0·123	0·123	0 0	+0·01
Oro	−0·101	+0·185	0·211	331 22	−0·08
Ikaruga	−0·101	+0·123	0·159	320 37	−0·19
Takanosu	−0·076	0·0	0·076	270 0	−0·19
Simomiya	+0·025	−0·216	0·217	173 24	+0·19

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Hinado	+0·050	−0·185	0·192	164° 53′	+0·08
Bazi	+0·050	−0·185	0·192	164 53	+0·12
Simokage	−0·050	−0·123	0·133	202 7	−0·11
Sindô	+0·101	−0·370	0·384	164 44	+0·11
Turui	+0·075	−0·185	0·200	157 56	−0·04
Kaodani	+0·126	−0·247	0·277	152 58	+0·18
Tôzima	0·0	−0·277	0·277	180 0	+0·01
Miyai	−0·101	−0·462	0·473	192 20	+0·02
Yuhune	0·0	−0·216	0·216	180 0	−0·13
Takehana	−0·101	−0·586	0·595	189 47	+0·04
Iwai	−0·076	−0·123	0·145	211 43	+0·01
Takui	+0·503	+0·092	0·511	79 38	−0·22
Kazima	+0·101	−0·123	0·159	140 37	+0·32
Miyasita	−0·050	−0·154	0·162	197 59	+0·21
Simoduka	+0·050	−0·154	0·162	162 1	+0·11
Matumoto	+0·075	−0·062	0·097	129 35	+0·34
Tada	−0·101	0·0	0·101	270 0	+0·08
Takesaka	−0·025	−0·185	0·187	187 42	−0·07
Onmata	−0·025	−0·370	0·371	183 52	+0·08
Tai	+0·176	−0·216	0·279	140 50	−0·36
Tuiyama	+0·151	−0·216	0·264	145 3	−0·27
Kei	+0·050	−0·277	0·281	169 46	−0·16
Yasiro	−0·277	−0·308	0·414	221 58	−0·07
Simoyama	−0·277	−0·586	0·628	201 10	−0·05
Ootani	+0·025	−0·308	0·309	175 22	−0·02
Uyama	+0·126	−0·185	0·224	145 45	−0·06
Komono	−0·101	−0·339	0·354	196 35	+0·06
Aitani	+0·101	−0·123	0·159	140 37	+0·25
Sibayama	0·0	−0·031	0·031	180 0	+0·13
Yasuki	0·0	−0·123	0·123	180 0	+0·16
Ootuki	+0·050	−0·185	0·192	164 53	−0·13
Morio	+0·101	−0·247	0·267	157 46	−0·04
Mihirakisan	+0·050	−0·277	0·281	169 46	−0·08
Hôtaku	−0·076	−0·154	0·172	206 16	−0·12

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Hyôtani	+0·101	−0·185	0·211	151° 22′	−0·09
Tadati	0·0	−0·216	0·216	180 0	0·0
Nanmeizan	0·0	−0·185	0·185	180 0	−0·08
Kimura	−0·101	−0·154	0·184	213 16	−0·04
Tôridake	−0·126	−0·186	0·224	214 15	+0·18
Nakahudi	−0·227	−0·339	0·408	213 48	−0·10
Okuhudi	−0·151	−0·154	0·216	224 26	−0·04
Akahanamura	−0·076	0·0	0·076	270 0	−0·20
Sidani	+0·050	−0·247	0·252	168 33	+0·08
Idusi	+0·050	−0·247	0·252	168 33	+0·08
Hosomi	+0·151	−0·123	0·195	129 10	+0·10
Terasaka	0·0	−0·123	0·123	180 0	+0·05
Kamimura	+0·202	−0·123	0·236	121 20	+0.10
Nyûdô	+0·050	−0·062	0·080	141 7	+0·11
Kawami	+0·101	+0·247	0·267	22 14	+0·11
Okuyane	+0·025	−0·247	0·248	174 13	−0·02
Hirayama	−0·176	−0·216	0·279	219 10	−0·02
Sirodani	−0·202	−0·185	0·274	227 31	−0·12
Aida	−0·126	−0·185	0·224	214 15	−0·10
Myôkenyama	−0·151	−0·092	0·177	238 39	−0·08
Sasaki	−0·126	−0·031	0·130	256 11	−0·01
Miyama	−0·101	−0·031	0·106	252 56	−0·02
Nisidani	−0·101	0 0	0·101	270 0	−0·01
Katama	−0·176	−0·216	0·229	199 23	+0·07
Zôrayama	−0·126	+0·092	0·156	306 8	−0·05
Kayano	−0·176	+0·154	0·234	311 11	+0·15
Utiumi	0·0	+0·062	0·062	0 0	+0·01
Otomi	−0·126	+0·185	0·224	325 45	−0·39
Okurue	−0·176	+0·123	0·215	304 57	−0·26
Kurogane	+0·151	−0·031	0·154	101 36	−0·16
Isitani	−0·477	+0·678	0·829	324 52	−0·03
Sarugao	−0·452	+0·216	0·501	295 32	0·0
Hê	−0·754	+0·616	0·974	309 15	−0·15
Nimatu	−0·553	+0·431	0·701	307 56	−0·01

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Oohira	−0·955	+0·709	1·189	306° 35′	−0·27
Takinoyama	−0·427	+0·308	0·526	305 48	+0·07
Kasayama	−0·478	+0·401	0·624	310 0	−0·04
Tumo	−0·528	+0·247	0·583	295 4	−0·11
Ooisi	−0·905	+0·586	1·078	302 55	−0·17
Kubo	−0·679	+0·431	0·804	302 24	−0·15
Obama	−0·553	+1·171	1·295	334 43	−0·16
Mitinoku	−0·955	+0·801	1·246	309 59	−0·20
Hatadani	−0·478	+0·339	0·586	305 21	−0·15
Ootani	−0·981	+0·924	1·348	313 17	−0·32
Moriage	−0·503	+0·431	0·662	310 36	+0·04
Gamatani	−0·754	+0·493	0·901	303 11	−0·24
Terayama	−0·553	+0·339	0·649	301 31	−0·08
Inunegasira	−0·629	+0·431	0·762	304 25	−0·27
Naya	−0·880	+0·832	1·212	313 24	−0·13
Wasigasaki	−0.604	+0·247	0·653	292 14	+0·04
Asago	−1·257	+1.048	1·637	309 49	−0·52
Tunoduki	−0·503	+0·308	0·590	301 29	−0·18
Kongôsan	−0·604	+0·678	0·908	318 18	−0·20
Sengokuyama	−0·579	+0·370	0·687	302 35	+0·01
Dake	−0·604	+0·462	0·760	307 25	−0·31
Yada	−0·931	+1·079	1·425	319 13	−0·34
Arai	−0·025	−1·233	1·233	181 10	+0·26
Akasaka	−0·881	+0·832	1·212	313 22	−0·25
Takao	−0·730	+0·647	0·975	311 33	−0·21
Yanaganaru	−0·604	+0·555	0·820	312 35	−0·35
Nisiyama	−0·101	−1.356	1·360	184 16	+0·24
Yasuke	−0·604	+0·431	0·742	305 31	−0·05
Mineyama	−0·906	+1·233	1·530	323 41	−0·22
Ainome	+0·025	−0·986	0·986	178 33	+0·33
Takase	−0·755	+0·955	1·217	321 40	+0·01
Kidumiyama	−0·554	+0·801	0·974	325 20	+0·21
Nisitani	−0·503	+0·555	0·749	317 49	−0·13
Hiziyama	0·0	−0·894	0·894	180 0	0·0

(*to be continued.*)

Table I. C. (*continued.*)

Triangulation Point	u	v	$\sqrt{u^2+v^2}$	$tg^{-1}\frac{u}{v}$	w
	m	m	m		m
Mititani	−0·478	+0·678	0·830	324° 49′	−0·04
Minamitani	−0·579	+0·524	0·781	312 9	−0·16
Byôbuyama	−0·101	−0·555	0·564	190 18	+0·32
Yakedôsi	+0·076	−0·709	0·713	173 53	+0·04
Misakayama	−0·428	+0·894	0·991	334 25	+0·24
Dôgatani	−0·504	+0·462	0·684	312 31	0·0
Kaya	+0·050	−0·524	0·526	174 33	−0·06
Kaitanidake	+0·050	+0·062	0·080	38 53	+0·34
Yosidu	−0·554	+0·431	0·702	307 53	−0·06
Sedoyama	−0·453	+0·431	0·625	313 34	−0·02
Oogatani	−0·403	+0·247	0·473	301 30	−0·31
Kanase	−0·202	+0·277	0·343	323 54	−0·17

Now that we have known the horizontal and vertical displacements of the third order triangulation points densely distributed over the district, we are able to proceed into a more detailed discussion on the crust deformation in this district than have hitherto been. Making use of the results given in the tables, the lines of equal eastward and northward displacements, u and v, are constructed as shown in Fig. 3 and Fig. 4. There were actually remarkable discontinuities in these displacements across the Gômura and Yamada seismic faults which were produced at the time of the earthquake of 1927, but the lines of equal eastward and northward displacements were drawn as if they were continuous throughout and were rapidly varying in these fault regions. This is merely for the sake of simplicity, for our final object is to find how the strain would be distributed on a hypothetical elastic body when the points on it are made to move just in the same manner as the corresponding points on the actual earth's crust in the district. It must be emphasised that by saying so we never assume the earth's crust to be ideally elastic. The lines of equal eastward and northward displacements were given in the writer's previous paper[3] which were constructed using as data the results of the revision of the second order triangulation. There are minor differences between the present figures and the corresponding former ones, which however are by no means essential. At any rate, it is note-

3) C. TSUBOI, *Bull. Earthq. Res. Inst.*, **8** (1930), 153

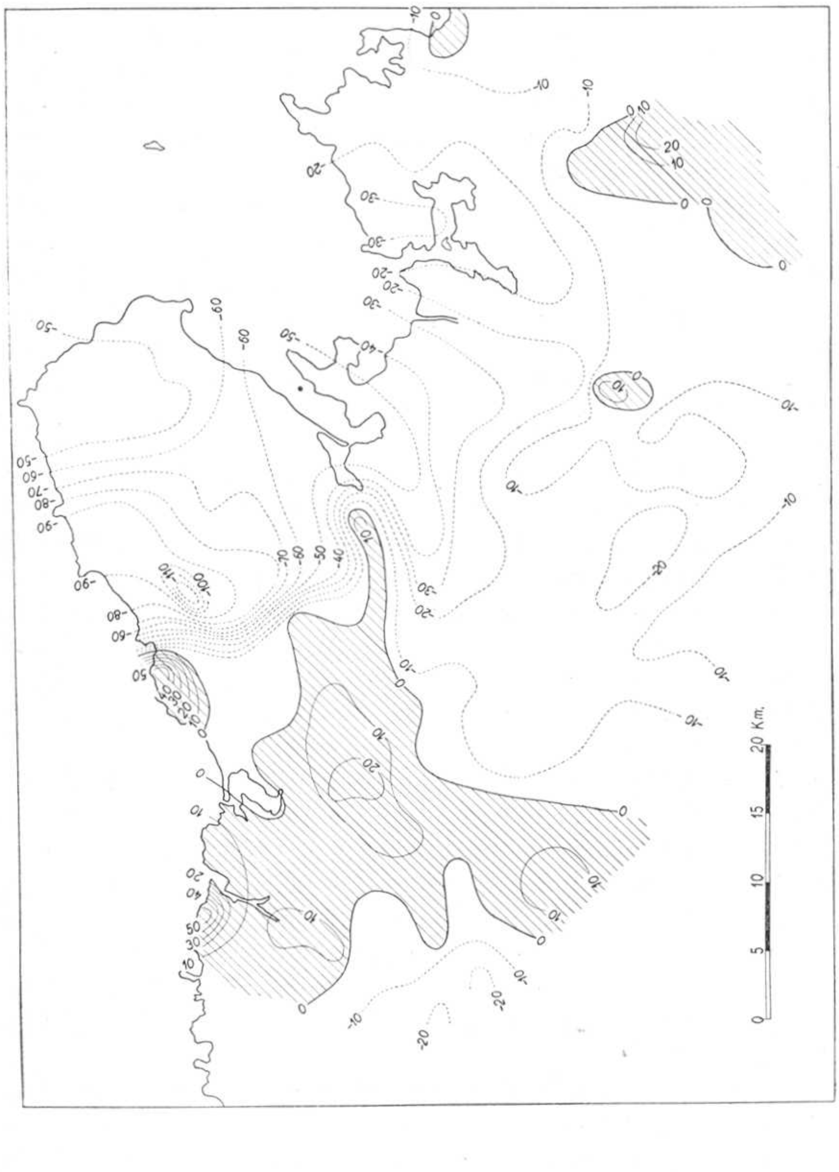

Fig. 3. Lines of Equal Eastward Displacement in cm.

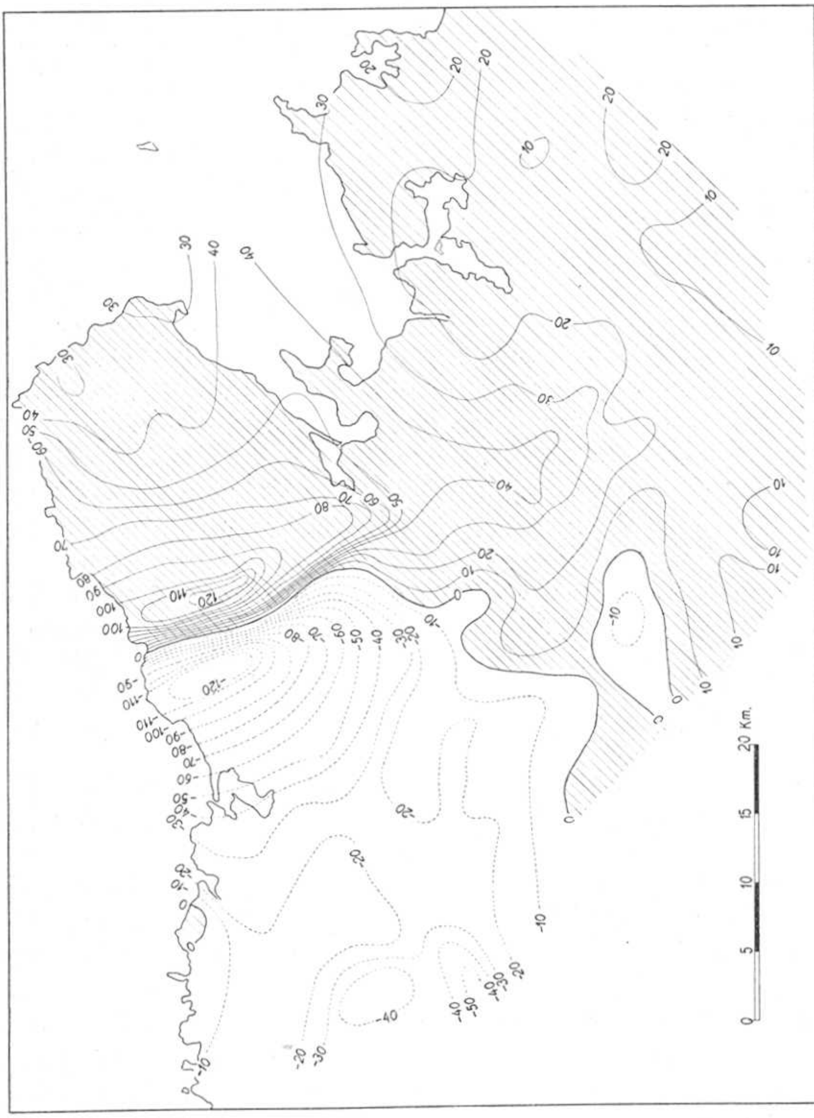

Fig. 4. Lines of Equal Northward Displacement in cm.

worthy that the contour lines are very much crowded along the two seismic faults while in other parts of the district, especially in the Tango peninsula, they are thinly distributed. This will be made clearer when the lines of equal spatial gradient of these displacements, $\frac{\partial u}{\partial x}$, $\frac{\partial v}{\partial y}$, $\frac{\partial u}{\partial y}$, $\frac{\partial v}{\partial x}$, are constructed, the latter two of which being shown in Fig. 5 and in Fig. 6. The calculation of these quantities was effected in the following manner. The maps of the Tango district that show the lines of equal eastward and northward displacements were divided into rectangular meshes of 3 km^2 by means of a series of parallel lines with EW and NS trends. After finding the values of u and v at every second mesh points by means of graphical interpolation, the longitudinal and horizontal differences of these values were taken as the values of $\frac{\partial u}{\partial y}$ and $\frac{\partial v}{\partial x}$ at the middle mesh points. While the aboslute values of these quantities are especially large along the two seismic faults, there are also several isolated regions scattered here and there in the district in which the values are relatively large as compared with those in their environs. The geological significance of the distribution of such isolated regions has already been discussed in the previous paper.[4)]

Making use of the values of the spatial gradients of the eastward and northward displacements thus obtained, we can now calculate the three components of strain, viz. dilatation $\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)$, rotation $\frac{1}{2}\left(\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x}\right)$, and shear $\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)$, the distribution of which quantities are shown in Figs. 7, 8, and 9. There is again no essential difference between these figures and the corresponding ones given in the previous paper.

As to the dilatation, it has been suggested[5)] that there seems to exist a positive correlation between the dilatation at a point and the vertical upheaval of the same point and this was especially clear in the previous analysis. Though this correlation is seen to be also existing in the present analysis when Fig. 2 and Fig. 8 are compared with each other, it seems not to be a very close one. If we read off in Fig. 7 the values of dilatation at the triangulation points and find the amounts of upheaval w for the corresponding points in Table I, we can construct a correlation diagram for these two quantities which is shown in Fig. 10. Though

4) *loc. cit.*

5) T. Terada and N. Miyabe, *Bull. Earthq. Res. Inst.*, 7 (1929), 223.
C. Tsuboi, *ibid.*, 8 (1930), 153.
T. Terada, *Proc. Imp. Acad.*, 6 (1930), 53.

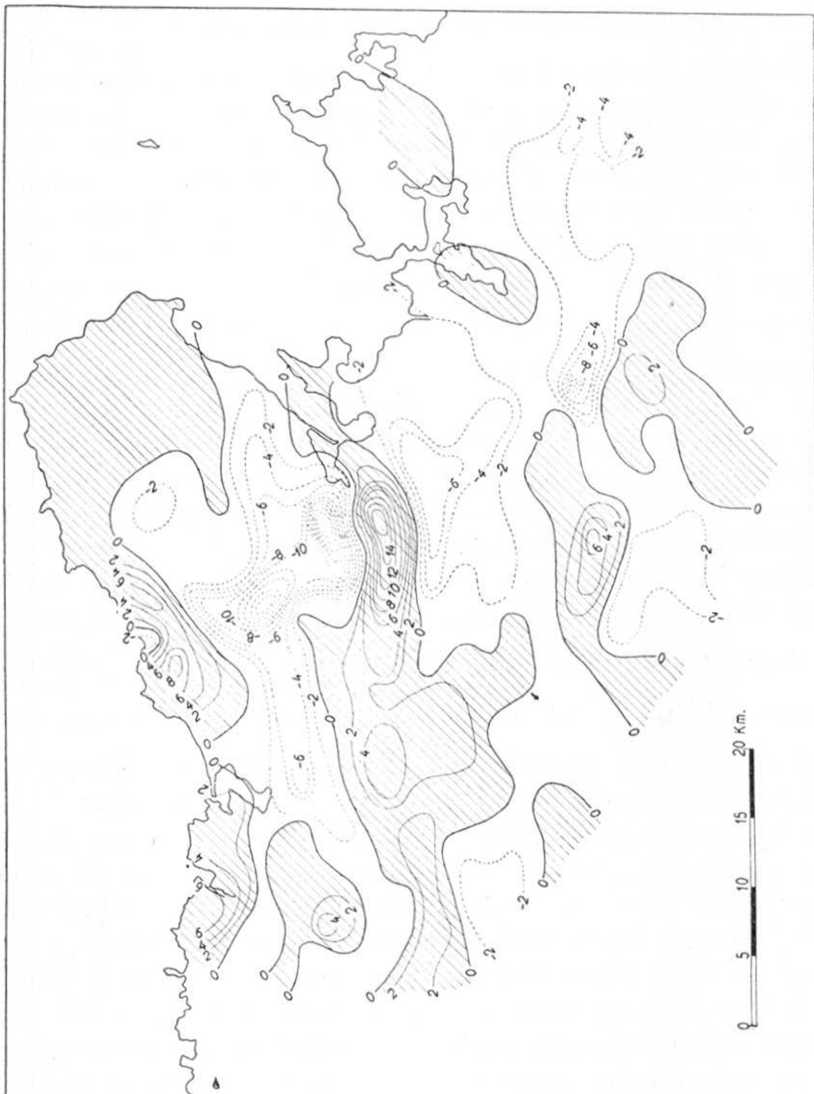

Fig. 5. Lines of Equal Northward Gradient of Eastward Displacement in 10^{-5}.

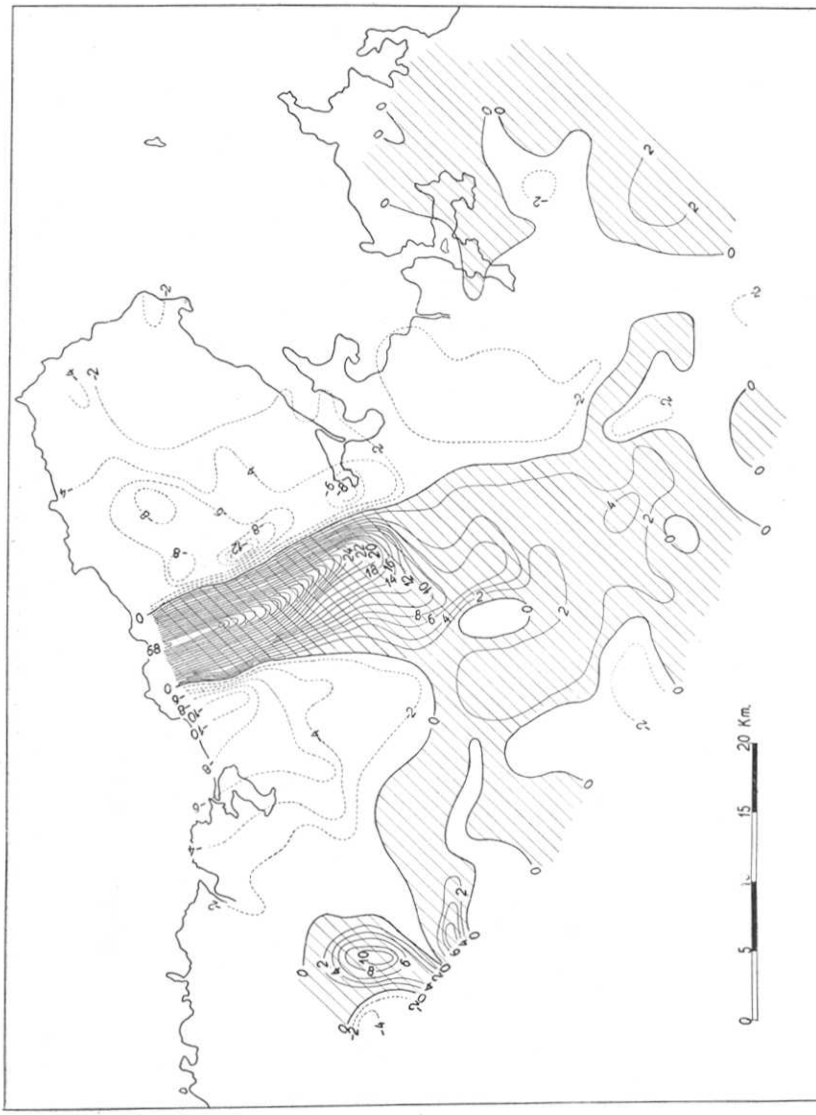

Fig. 6. Lines of Equal Eastward Gradient of Northward Displacement in 10^{-5}.

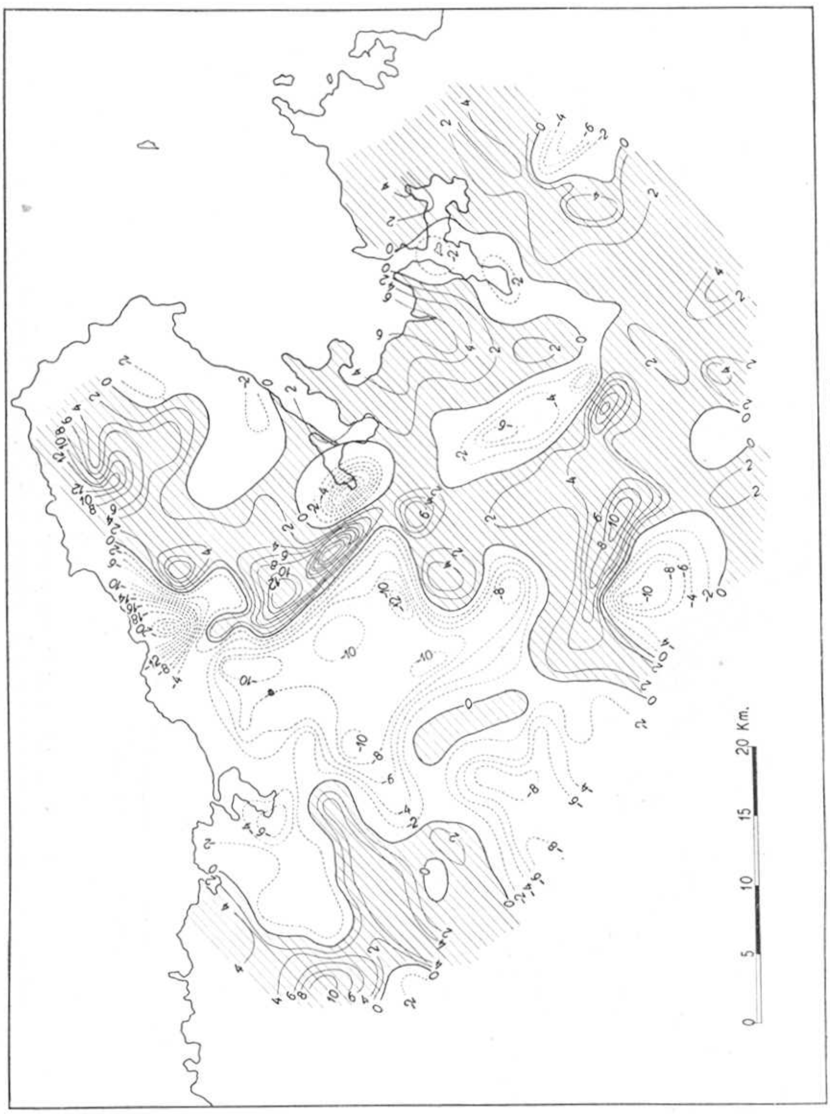

Fig. 7. Lines of Equal Dilatation $\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)$ in 10^{-5}.

Fig. 8. Lines of Equal Rotation $\frac{1}{2}\left(\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x}\right)$ in 10^{-5}.

Fig. 9. Lines of Equal Shear $\frac{1}{2}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)$ in 10^{-5}.

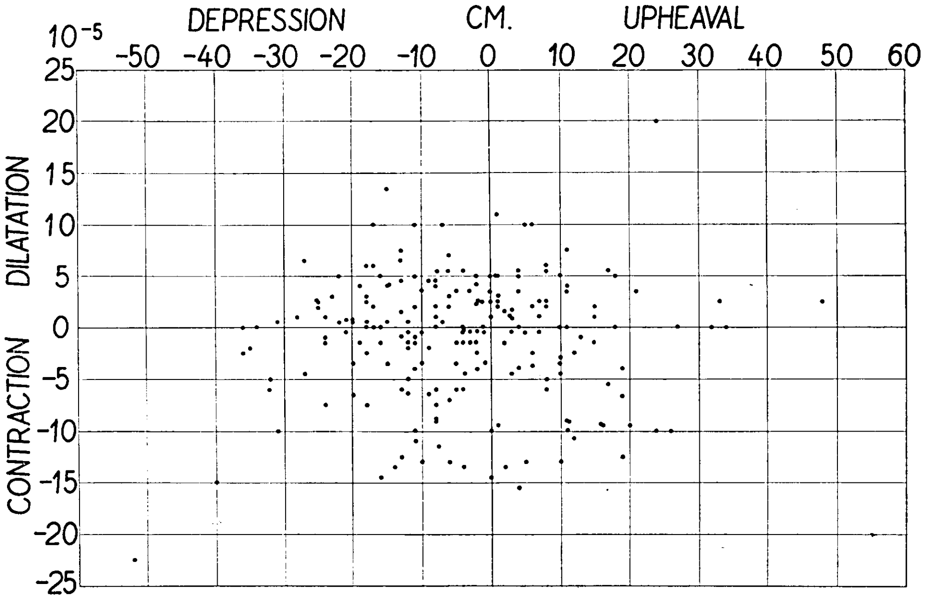

Fig. 10. Correlation Diagram for the Vertical Displacement of the Triangulation Points and Dilatation in their Immediate Neighbourhood.

the correlation between these two quantities is roughly positive, it is very much loose than it was for the provious calculation. This may be. because of the effects of local irregularities which were smoothed out in the previous calculation based on the results of the secondary triangulation but remained as such for the present calculation based on the results of the third order triangulation. Thus it seems to the writer that the suggested relation between the two quantities is a regional but not of a local one, holding good for the average values within regions of sensible extent. This circumstance is somewhat similar with that for the correlation between the topography of a certain district and its isostatic effect on the intensity of gravity known as regional and local isostasy.

As to the distribution of the lines of equal rotation, it is remarkable that the rotation is small and positive and sensibly uniform throughout the Tango peninsula. This indicates that the peninsular block made a small clockwise rotation as a whole without sensible deformation in it.

We can now construct the lines of equal maximum shear which is given by

$$\sigma=\sqrt{\left(\frac{\partial u}{\partial x}-\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)^2}.$$

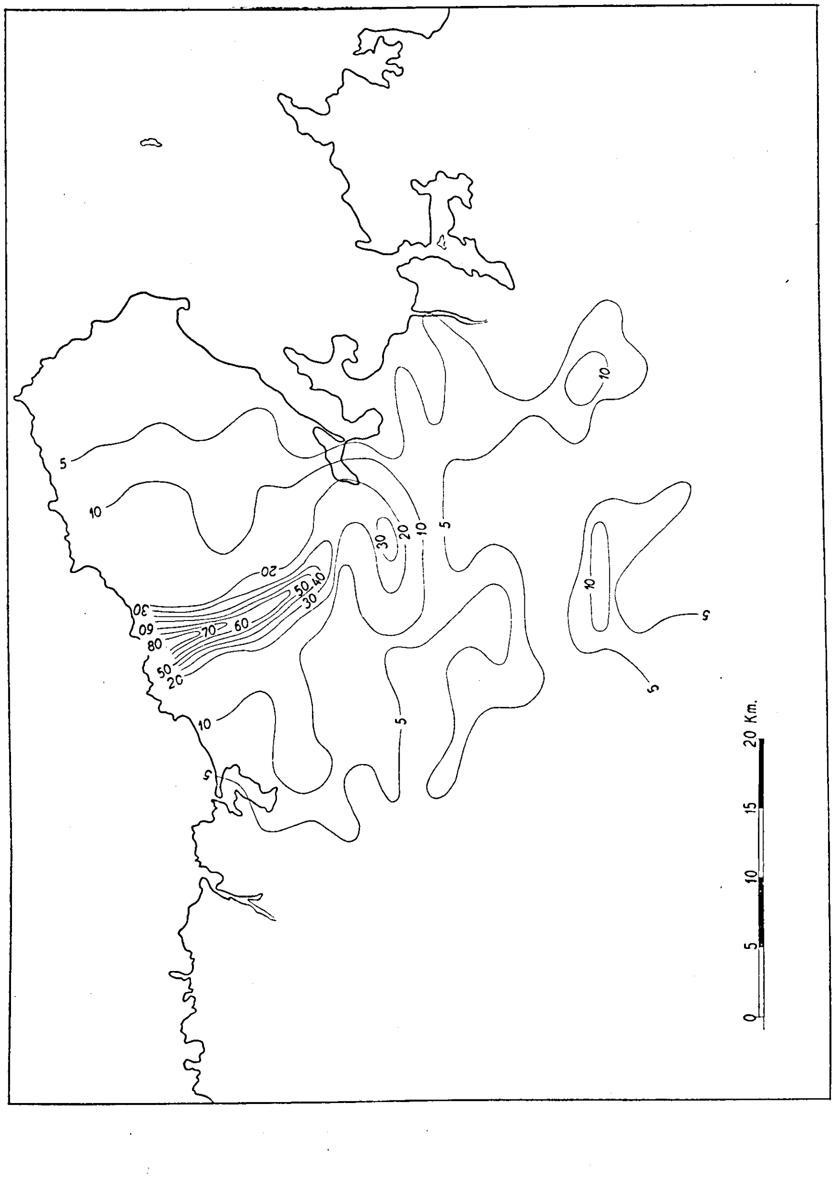

Fig. 11. Lines of Equal Maximum Shear in 10^{-5}.

The distribution of this quantity is shown in Fig. 11. This is naturally large along the two seismic faults. There are moreover two isolated regions in which maximum shear exceeds the value of 10×10^{-5}. It is not difficult to correlate these narrow regions with minor tectonic lines in the district but there seems no evident reason so far why these lines alone were active while others of equal geological significance were kept intact notwithstanding the earthquake disturbance.

Finally for the purpose of visualising the deformation of the earth's crust in the district, magnitudes $\gamma_1\gamma_2$ and the directions $\theta_1\theta_2$ of the principal axes of strain ellipses were calculated. These quantities are given by the following expressions and can be obtained from the spatial gradients of components of horizontal displacements already calculated.

$$\gamma_{1,2}=\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\pm\sqrt{\left(\frac{\partial u}{\partial x}-\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2},$$

$$\tan\theta_{1,2}=\frac{\gamma_{1,2}-2\dfrac{\partial u}{\partial x}}{\dfrac{\partial u}{\partial y}+\dfrac{\partial v}{\partial x}}.$$

In Fig. 12, the amount of principal strains are shown by thick and broken lines along the corresponding directions according as they are elongation and contraction respectively. The strain ellipses have very large values of ellipticity along two zones trending perpendicularly with each other. They are coincident in position with the Gômura and Yamada seismic faults both of which were produced at the time of the earthquake of 1927. Along the Gômura fault, the strain ellipses are elongated in the direction of the fault and contracted across the fault, thus it is naturally concluded that the Gômura fault was produced by a contracting movement of the earth's crust. The case is different for the Yamada fault. The trend of this fault is along the direction of maximum shearing strain and this fault must have thus been produced by a shearing movement of the earth's crust. It is a well-known fact that some material fail first against compression while others first against shearing. It seems to be of no small interest that we have here two different cases in which the material of the earth's crust yielded against two different kinds of deformations. The distribution of the strain ellipses in the neighbourhood of the Gômura fault seems to indicate that this fault was elongated more southward than it was observable on the surface of the earth's crust at the time of the earthquake of 1927.

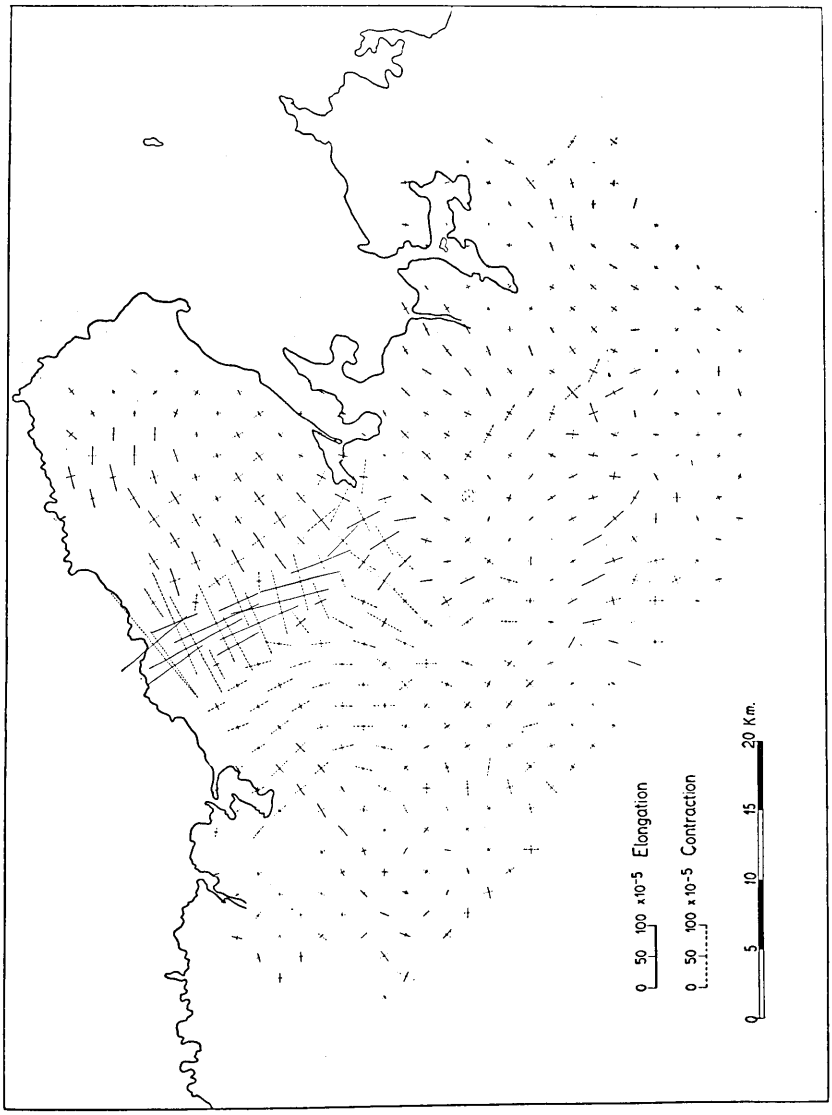

Fig. 12. Principal Axes of Strain Ellipses.

In conclusion, the writer wishes to express his sincere thanks to Professor Torahiko TERADA for his interests in the present work. Thanks are also due to Mr. Akira JITSUKAWA for his assistance in the calculation involved in this paper and in preparing the figures contained in it.

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28. 昭和二年丹後地震に關聯せる丹後地方の地殼變形に關する研究（第四報）

地震研究所　坪　井　忠　二

此の論文は丹後地震後、同地方に行はれた三等三角測量改測の結果を使つて、此の地方の地殼の變形を論じたものである。著者は前に二等三角測量改測の結果から、同様な問題を取扱つた事があるが、今度得られた結果は勿論夫と大差は無い。たゞ局部的の影響が目立つて來た。尚今度の計算では主な變形の軸を定めたので、此の地方の變形が一目で見られる様になつた。

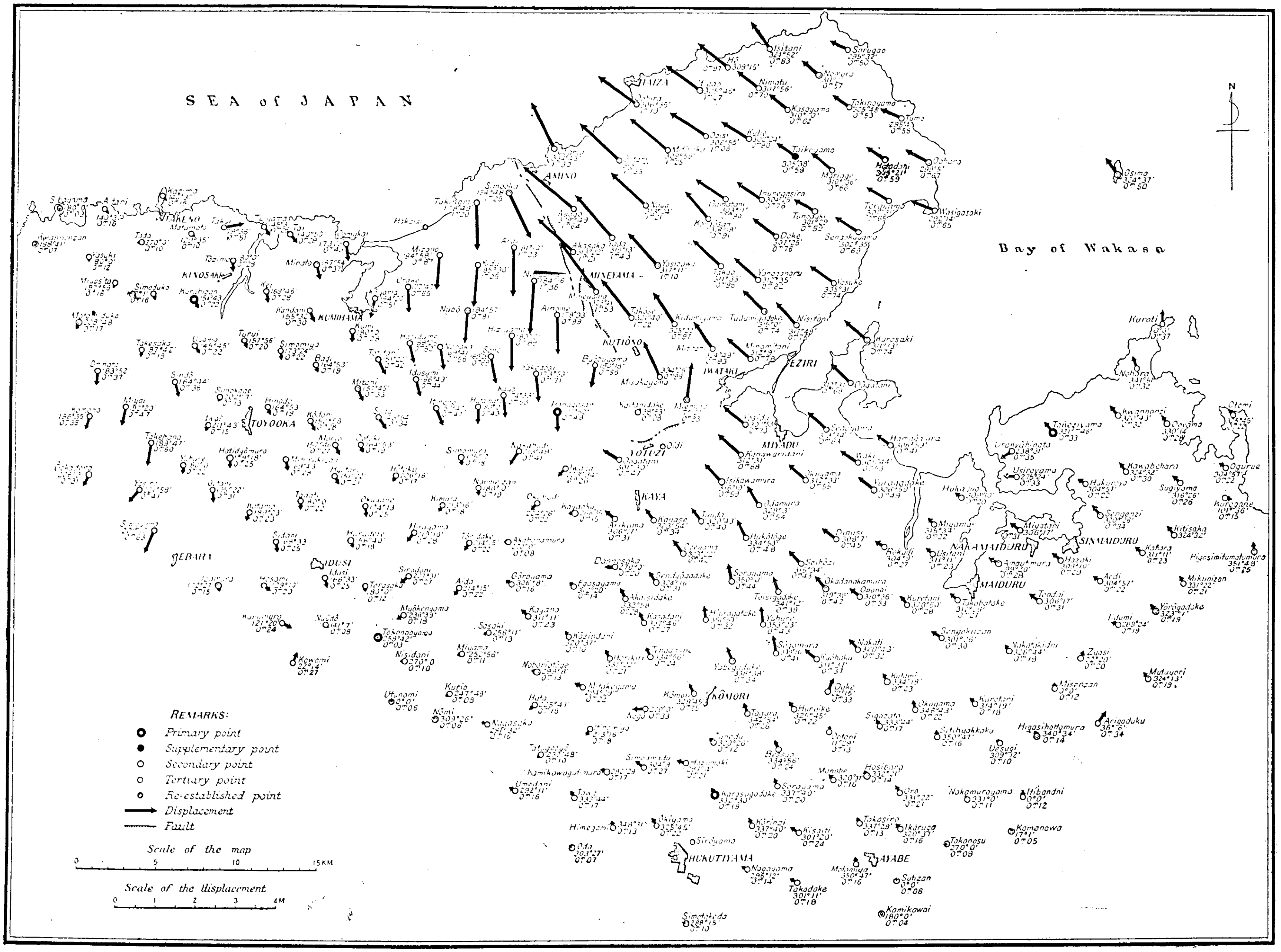

Fig. 1. Horizontal Displacements of the Triangulation Points in the Tango District.

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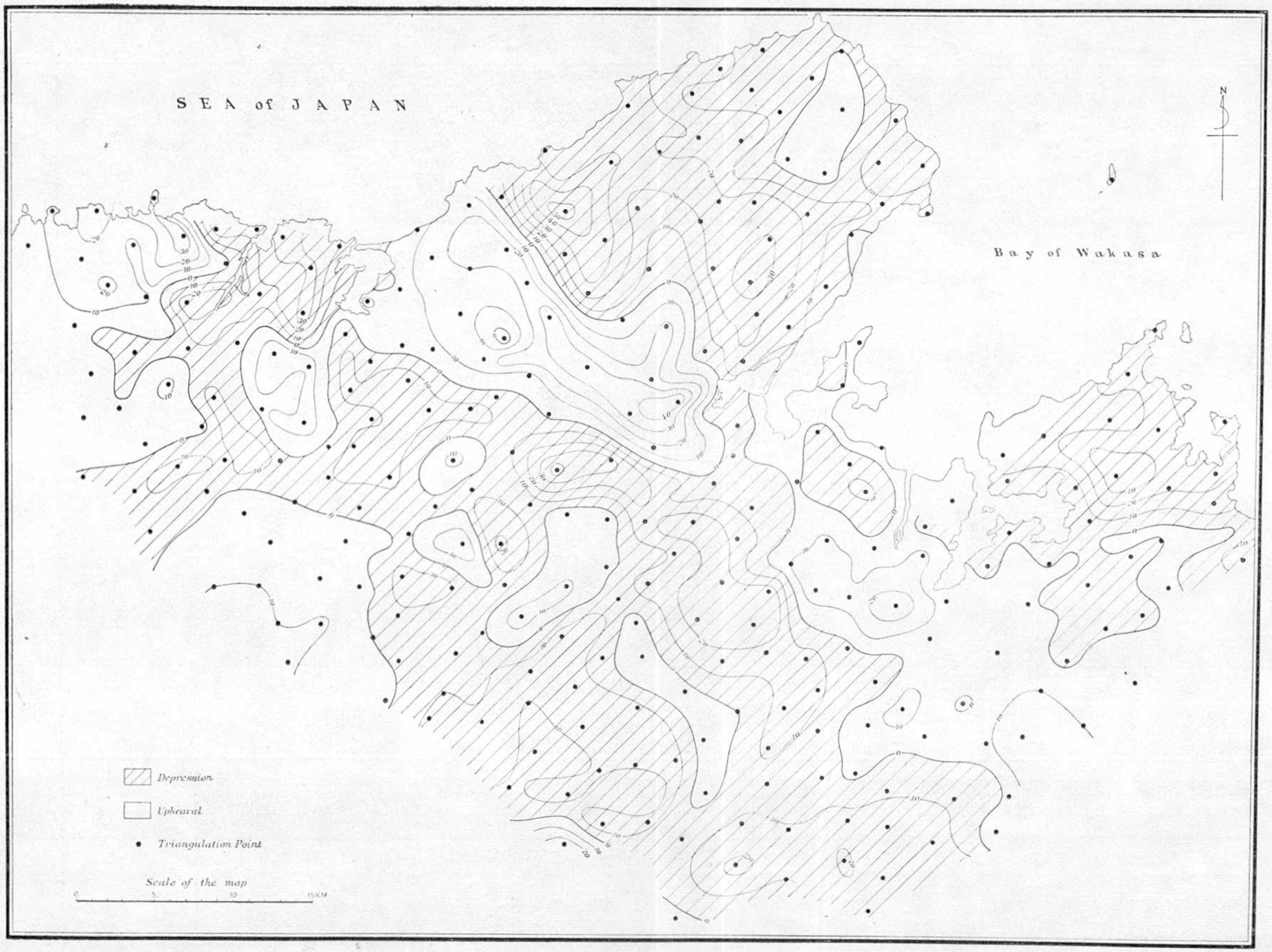

Fig. 2. Vertical Displacements of the Triangulation Points in the Tango District in cm.

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