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12. *Electro-Optical Measurement of Horizontal Strains Accumulating in the Swarm Earthquake Area (3).*

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Abstract

There have been repeated Geodimeter surveys in the Matsushiro and its adjacent areas since October, 1965. Their purpose is to study accumulation of horizontal strains at various stages of the seismic activity. The present paper will deal mainly with the strain events observed from September of this year, since the data for the earlier period were reported in the previous papers.

Strains still actively accumulated in Matsushiro during the period September to October. The base-lines of Sorobeku, Nishiterao and Zozan changed their length for +26, +22 and −3 cm, resulting in the total variation after the first survey as much as +116, +72 and −21 cm, respectively. In the remaining period (October-November), however, the authors observed no active accumulation of strains. It is notable that the base-lines of Sorobeku and Nishiterao recorded contraction in contrast with their former sense of deformation, extension. Similar kinds of information, suggesting the recent reversal of the strain activity mode, has been derived from levelings and tiltmeter observations, too.

Strain accumulations are less active in Wakaho, Nakano, and Omachi, in that order. Discussion is developed briefly on several notable aspects of strain events in these areas.

1. Introduction

The authors have been carrying out Geodimeter surveys in the northern part of Nagano Prefecture since October, 1965, as part of the ERI's expeditions for the Matsushiro swarm earthquakes. As reported in the previous two papers[1),2)], they repeated the surveys in Matsushiro

1) K. KASAHARA and A. OKADA, "Electro-Optical Measurement of Horizontal Strains Accumulating in the Swarm Earthquake Area (1)," *Bull. Earthq. Res. Inst.*, 44 (1966), 335-350.

2) K. KASAHARA, A. OKADA, M. SHIBANO, K. SASAKI and S. MATSUMOTO, "Electro-Optical Measurement of Horizontal Strains Accumulating in the Swarm Earthquake Area (2)," *Bull. Earthq. Res. Inst.*, 44 (1966), 1715-1733.

nine times during the period October, 1965 to September, 1966 and successfully discovered notable evidence for accumulation of horizontal strains there. Following these surveys they conducted two more surveys in the same area during the period of September to November, inclusive, in order to observe strain events associated with the third climax of the seismic activity. Surveys were carried out also in the Nakano and Wakaho areas to compare the data with those from the previous work.

One year before the beginning of the present activity, namely in November, 1964, the authors constructed a base-line network in Omachi, 30 km west of Matsushiro,[3] as one of the test areas for Geodimeter techniques (Fig. 1). The second survey was also carried out on the Omachi network during the above-stated period, because it seemed interesting to examine whether the tectonic movements in the said area were stimulated by the Matsushiro swarms or not.

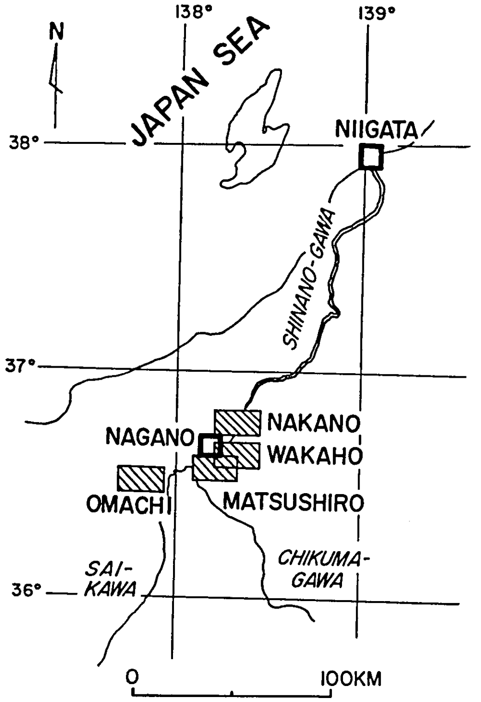

Fig. 1. Base-line networks constructed in the northern part of Nagano Prefecture.

2. Field Work

2.1. Repetition of surveys

The Matsushiro network The network consists of the three baselines, Sorobeku, Nishiterao and Zozan. Its detailed structure will not be explained here, as it has been introduced in the previous papers[4]. Surveys were repeated for two times during the present period as follows.

3) K. KASAHARA and A. OKADA, "Observation of Horizontal Strain Accumulation by Electro-Optical Means. 1. Construction of base-line nets in central Honshu, Japan," *Bull. Earthq. Res. Inst.*, 44 (1966), 1149-1165 (in Japanese).

4) *loc. cit.*, 1) and 2).

Survey X October 13-14, 1966 ,
Survey XI November 12, 1966 .

Table 1 gives the observational data on the Matsushiro network after correction for meteorological conditions, where D and ΔD denote the base-line length at each period and the change in their length counted from the first survey's data, respectively.

Strain accumulation during the September-October period was still as active as in the previous case. Particularly, the Sorobeku base-line recorded the extension of 26 cm in one month, resulting in the total extension after the first survey as much as 116 cm. The other base-lines, Nishiterao and Zozan, changed their length for +22 and −3 cm, respectively, giving the total extension of +72 and −21 cm. We may roughly say, therefore, that the Matsushiro area was subject to further accumulation of strains during the present period with its basic mode unchanged.

The seismic activity entered the third climax stage at the end of July, which continued for one or two months since then. As to the daily frequency of shocks, the highest activity in the present stage was observed late in August, which was followed by the decaying stage

Table 1. Changes in Base-Line Length

(a) Matsushiro Network

Base Line		Zozan		Nishi-terao		Sorobeku	
No.	Date	D	ΔD	D	ΔD	D	ΔD
		m mm	mm	m mm	mm	m mm	mm
I	Oct. 6-7, 1965	2381.612 (±3)	0	3154.286 (±5)	0	3062.912 (±4)	0
II	Nov. 15	.602 (±6)	− 10	.293 (±8)	+ 7	.938 (±10)	+ 26
III	Dec. 9	.624 (±2)	+ 12	.318 (±4)	+ 32	.994 (±2)	+ 82
IV	Mar. 2, 1966	.609 (±3)	− 3	.310 (±4)	+ 24	3063.025 (±3)	+ 113
V	Apr. 12-13	.574 (±2)	− 38	.388 (±2)	+102	.128 (±3)	+ 216
VI	Apr. 18	.570 (±0)	− 42	.383 (±4)	+ 97	.159 (±1)	+ 247
VII	May 5-6	.557 (±2)	− 55	.445† (±2)	+159†	.238 (±3)	+ 326
VIII	July 3	.534 (±3)	− 78	.569 (±4)	+283	.376 (±2)	+ 464
IX	Sep. 6-7	.449 (±2)	−163	.783 (±1)	+497		
	7-8	.440 (±0)	−172			.804 (±4)	+ 892
	8-9	.430 (±2)	−182				
X	Oct. 13-14	.402 (±0)	−210	3155.004 (±2)	+718	3064.068 (±3)	+1156
XI	Nov. 12	.393 (±2)	−219	3154.986 (±2)	+700	.016 (±2)	+1104

(to be continued)

Table 1.

(b) Wakaho Network (continued)

Base Line		Shimowada		Ohashi		Nuruyu			
No.	Date	D	ΔD	D	ΔD	D	ΔD	D	ΔD
		m mm	mm	m mm	mm	m mm	mm	m mm	mm
I	May 8, 1966	3293.666 (±2)	0	1890.526 (±0)	0	2027.019† (±3)	0		
II	July 5	.626 (±2)	− 40	.527 (±1)	+ 1			2026.350 (±1)	0
III	30-31	.672 (±3)	+ 6	.470 (±3)	−56	.004 (±3)	−15†	.367 (±2)	+17
IV	Nov. 14	.474 (±2)	−192	.437 (±2)	−89	2026.985 (±2)	−34		

(c) Nakano Network

Base Line		Okura		Imai		Sakurazawa	
No.	Date	D	ΔD	D	ΔD	D	ΔD
		m mm	mm	m mm	mm	m mm	mm
I	Mar. 4, 1966	1716.675 (±10)	0	2155.396 (±4)	0	3685.689 (±6)	0
II	Apr. 13	.677 (±1)	+ 2	.408 (±3)	+12	.671 (±1)	−18
III	Oct. 16	.653 (±1)	−22	.408 (±2)	+12	.637 (±2)	−52

(d) Omachi Network

Base Line		Shimizuzawa		Kashimaohashi		Satellite		Taira	
No.	Date	D	ΔD	D	ΔD	D	ΔD	D	ΔD
		m mm	mm	m mm	mm	m mm	mm	m mm	mm
I	Nov. 6-8, 1964	4353.406 (±2)	0	5109.366 (±4)	0	5350.802 (±2)	0	4226.711 (±3)	0
II	Oct. 9, 1966	.352 (±3)	−54						
	10**	.431 (±1)		.325 (±4)	−36*			.630 (±3)	0*

* tentative ** revised

† The corresponding figures in the previous papers should be revised as given here.

through September. From the viewpoint of crustal deformations, however, it was in September that we experienced the highest activity. In this month we observed notable development of land fractures at the northeastern foot of the Minakami-yama Hill, which were finally accompanied by the disastrous land-slide on September 17.[5] It was also in this period that the land around the Minakami-yama Hill upheaved at an abnormally high time-rate of one centimeter per day. Active strain accumulation between the surveys IX and X seems to harmonize with such kinds of surface evidence.

Comparison of the surveys X and XI leads us to a notable finding that an active extension was no more to be observed on either of the

5) R. MORIMOTO, K. NAKAMURA and Y. TSUNEISHI, Read at the Monthly Meeting of the Earthquake Research Institute, September 27, 1966.

base-lines during the October-November period. The detected change in the Sorobeku, Nishiterao and Zozan base-lines was very small and of contractive sense, i.e., −5, −2 and −1 cm, respectively. These data form a striking contrast to the previous activity in the former two lines, which continued an active extension from the beginning.

Evidence for the recent reversal of the strain accumulation mode was also discovered by levelings[6] and tiltmeter observations[7]. We may naturally conclude that the Matsushiro swarms had entered a new phase at that moment, so far as we are concerned with the strain aspects of the activity.

Wakaho network Structure of the network has been introduced in the previous papers[8], so that we will not repeat it here. In Table 1 (b) are given the data from the recent survey in comparison with the former surveys. During the period July to November, the Shimowada, Ohashi and Nuruyu base-lines changed their length in a contractive sense, i.e., −19, −3 and −2 cm, respectively. The cumulative sum of their change after the first survey (April, 1966) amounted to −19, −9 and −3 cm.

Nakano network Between the surveys II and III, the Okura and Sakurazawa base-lines changed their length for −20 and −3 cm (i.e., contraction), which is still of the order comparable with the supposed errors in observation (±1∼2 cm).

Omachi network Construction and the first survey on it were conducted in 1964, as part of the research project for the neotectonics in Japan. Its location and structure are illustrated in Figs. 1 and 2, respectively. Although its initial purpose was independent of the Matsushiro activity, it was considered very helpful for the present expeditions to repeat surveys here in order to watch the strain accumulation related to the Matsushiro swarms.

As is listed in Table 1 (d), the authors observed a length's change of −5 cm in the Shimizuzawa base-line, which is a small but significant contraction. In the other base-lines, however, they failed to find changes. The bench mark at the base-station (Museum) had been removed by accident just after the survey on the Shimizuzawa base-line. The value

6) I. TSUBOKAWA *et al.*, Read at the Monthly Meeting of the Earthquake Research Institute, October 25, 1966.

7) T. HAGIWARA and J. YAMADA, Read at the Monthly Meeting of Earthquake Research Institute, December 27, 1966.

8) *loc. cit.*, 2).

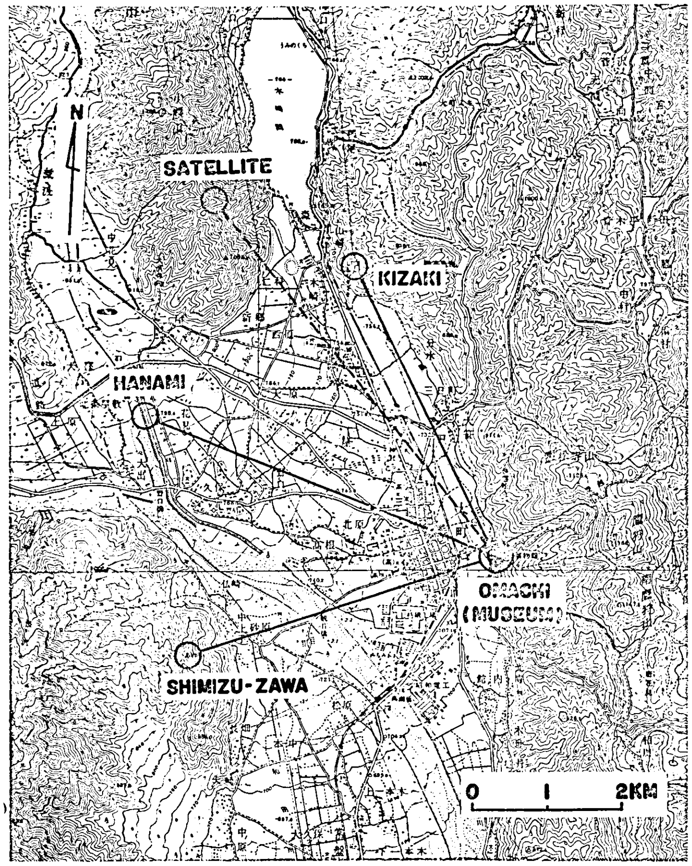

Fig. 2. Structure of the Omachi base-line network.

for the Kashimaohashi and Taira base-lines refer, therefore, to the mark newly constructed at the base. Offset of the new mark to the lost one is not certain except in the direction to Shimizuzawa (+8 cm). Let us assume, therefore, that the Taira base-line underwent no strain between 1964 and 1966. That is to say, the observed difference in the Taira base-line between the two surveys (+5 cm) is principally due to the new mark's offset in this direction. Contraction of the Kashimaohashi base-line (−4 cm) is a tentative value thus derived.

3. Discussion

Fig. 3 illustrates the accumulation of linear strains along the three base-lines in Matsushiro. Steeply developing curves reflect the activity

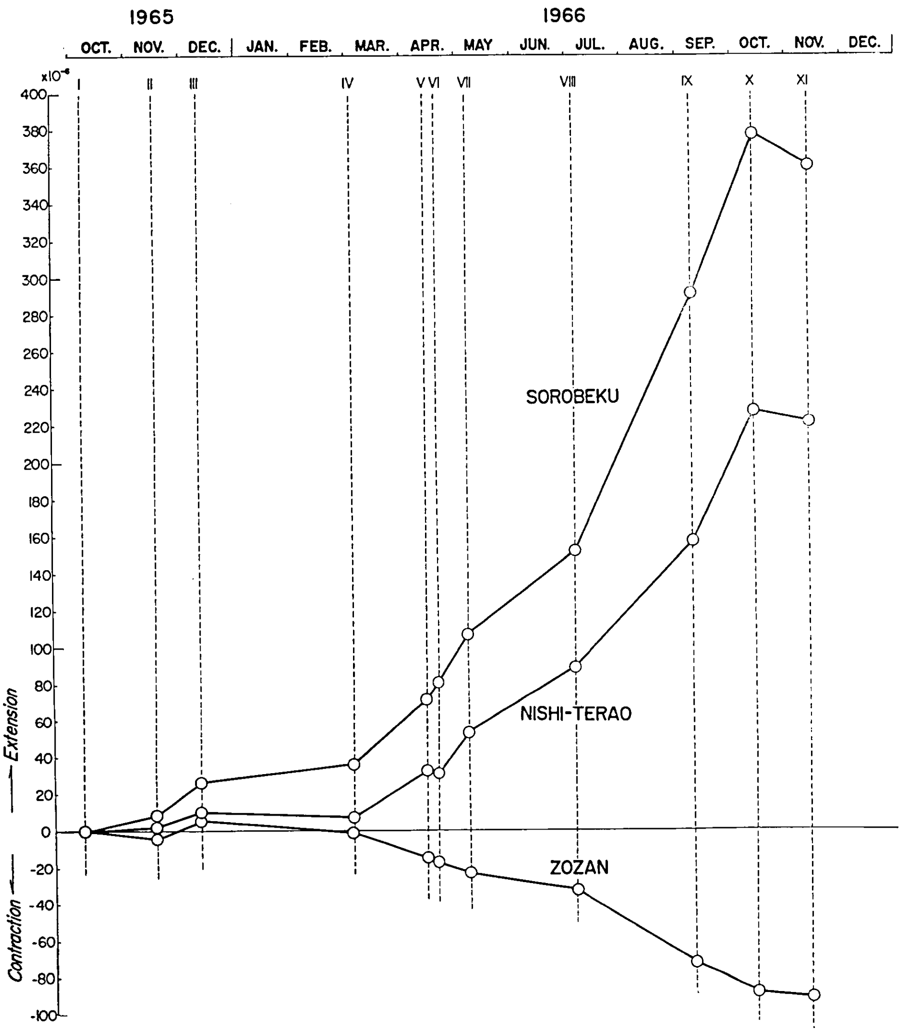

Fig. 3. Accumulation of strains (Matsushiro).

in the third climax period. Particularly active was as before the Sorobeku base-line, which recorded strain accumulation of 370×10^{-6} during the past one year. It is doubtful, of course, whether we can still take the previous assumption on elastic deformation. However, for simplicity's sake, let us apply it tentatively to the following discussion comparing these data on the same standard. Thus we observe the accumulated strains in the Nishiterao and Zozan lines to be 250×10^{-6} and -90×10^{-6},

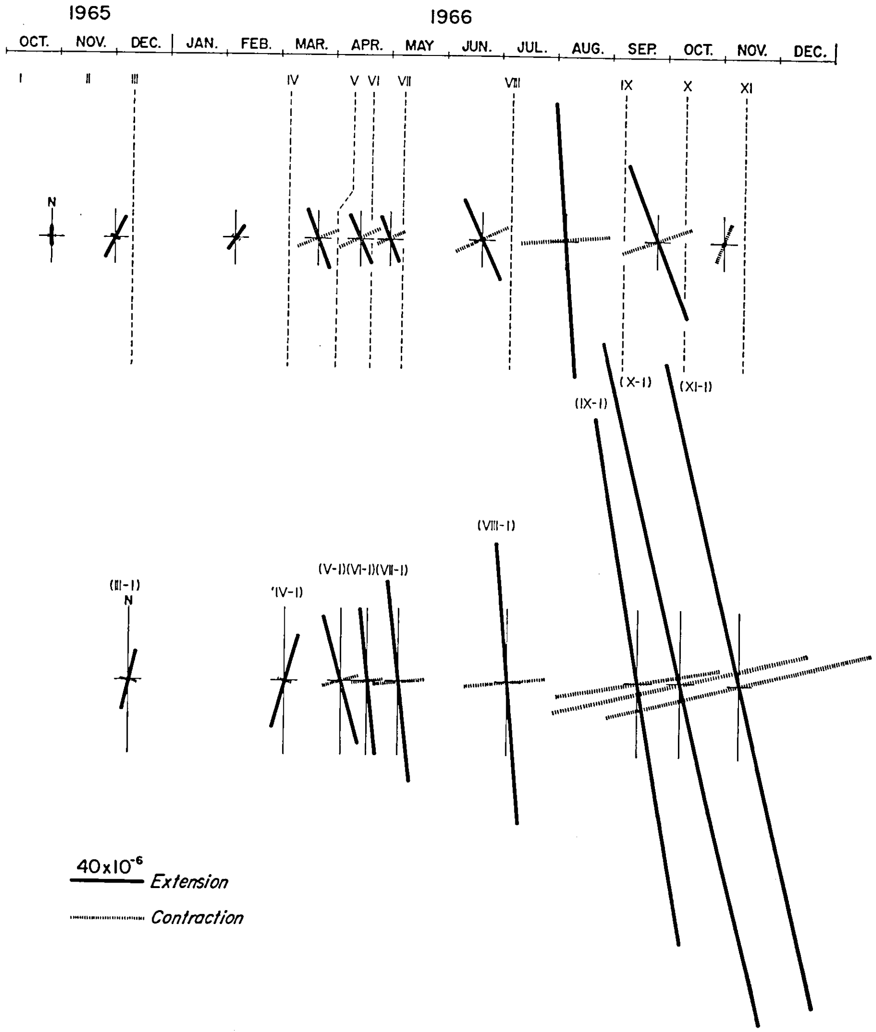

Fig. 4. Principal axes of horizontal strains computed for various periods of the repeated surveys (Matsushiro). Figures in the upper and lower groups illustrate partial and cumulative features, respectively.

respectively.

It is remarkable in the figure that the curves ceased developing at about the period of the tenth survey and that the upper two since turned into decaying ones. Reversal of the strain mode has also been proved by the other observations. It is doubtless, therefore, that the present effect has some essential bearings on the activity in Matsushiro.

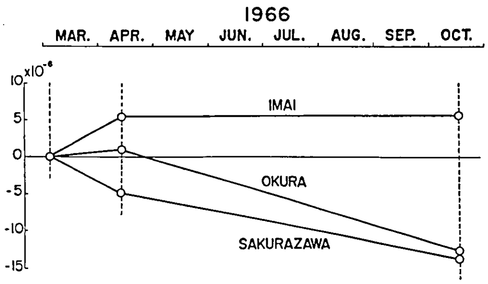

Fig. 5. Accumulation of horizontal strains (Nakano).

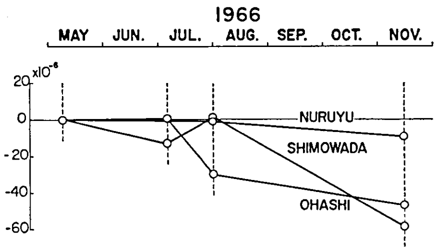

Fig. 6. Accumulation of horizontal strains (Wakaho).

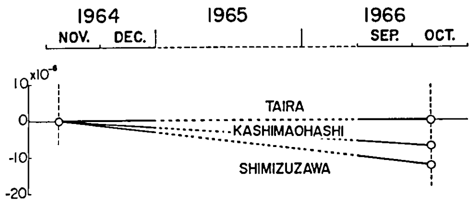

Fig. 7. Accumulation of horizontal strains (Omachi).

Observed strains are reduced to principal axes and are illustrated in Fig. 4, where the figures in the upper and lower series represent the partial and cumulative features, respectively. It is interesting that the partial feature for the (X-XI) period is represented by a single contraction axis in the direction NE-SW. This is the direction normal to the extension of the fracture zone running at the foot of Minakami-yama. Precise levelings and tiltmeter observations have revealed that the local area underwent a considerable amount of recovery tilt toward SW in October. Therefore the observed contraction in NE-SW might be partly attributed to the tilting of the mountain body. This effect must be

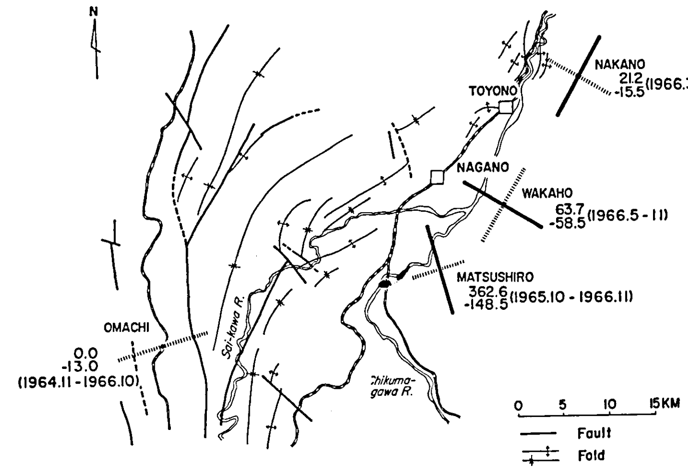

Fig. 8. General features of strain accumulation in the northern part of Nagano Prefecture. Direction of the principal axes is illustrated by thick lines (solid: positive, broken: negative), whereas the magnitude of each axis is given by the attached figures in the 10^{-6} unit. Periods of the surveys are given in the brackets.

corrected as soon as possible to enable us to discuss the strain activity more precisely.

Strain accumulation in the Wakaho, Nakano and Omachi networks is illustrated in Figs. 5-7, respectively. Fig. 8 is drawn to illustrate the mode of strain accumulation in the northern part of Nagano Prefecture schematically, where the direction and relative amplitude of the principal axes in each area are represented by thicks lines. The figures attached to each axis represent its amplitude in the 10^{-6} unit, whereas periods of the respective surveys are given in brackets for the sake of reducing strain accumulation to the same time base.

Generally speaking, Matsushiro is doubtlessly most active among them, and the strains are less active in Wakaho, Nakano and Omachi, in that order. A notable evidence in the figure is the Wakaho's axes which are in the direction similar to that of Matsushiro. As discussed in the previous paper[9], this might be an evidence for the fact that the horizontal strains with the commom mode (extensile in NS, and contractive in EW) spreads outward from Matsushiro. Judging from the relatively small amplitude of the Wakaho's axes, however, this area may form the northeastern boundary of the active deformations.

9) *loc. cit.*, 2).

The strain rate in Nakano is further low, being one-third or a quarter of the Wakaho's data, although it is still higher than the normal tectonic rate in Japan estimated by various authors[10,11]. We may suspect, therefore, that the tectonic conditions in Nakano are also stimulated by the events in Matsushiro, directly or indirectly, to undergo strain accumulation at a relatively high rate. More interesting is the direction of the contractive axis of tectonic structures there. Recalling the well-known fact that these structures are very young in geological sense, we may suppose the present strain accumulation to be a part of the tectonic process which is still active in this area.

It is hard to develop discussion on the Omachi's data, because they are based on the tentative assumptions as stated in the previous section. However, we may safely conclude that the strain did not accumulated there during the past two years to the extent as to exceed the order of 10×10^{-6}, very much.

4. Conclusions and acknowledgement

The authors repeated Geodimeter surveys in Matsushiro and its adjacent areas for the purpose of observing horizontal strains associated with the swarm activity. Through the recent surveys, which were conducted during the period September to November, they exposed the following as notable evidence.

1) Strain accumulation in Matsushiro was still active in the September-October period. Resulting from this, the Sorobeku, Nishiterao and Zozan base-lines recorded the total change of $+116$, $+72$ and -21 cm, respectively, counted from the first survey. In the period October to November, however, the authors observed no extension, but rather contraction even in the Sorobeku and Nishiterao base-lines. Reversal of strain mode at about the October period was also proved by levelings and tiltmeter observations.

2) Strain accumulation in Wakaho is far less active than in Matsushiro. The pattern of the principal axes, which is very similar to that of Matsushiro, seems to suggest that the horizontal deformation with the common mode (extensile in NS, and contractive in EW) "leaks"

10) K. KASAHARA and A. SUGIMURA, "Spatial Distribuition of Horizontal Secular Strain in Japan," *J. Geod. Soc., Japan*, **10** (1964), 139-145.

11) T. MATSUDA, K. NAKAMURA and A. SUGIMURA, Read at the Monthly Meeting of the Earthquake Research Institute, October 25, 1966.

out here from Matsushiro with its magnitude reducing.

3) The mode of strain accumulation in Nakano differs significantly from the former two. Particularly interesting is the direction of the contractive axis that is perpendicular to the axes of folding structure in this area. This might suggest that the tectonic movements is still developing here. The time rate of the strain accumulation is much lower than that of Wakaho's data, but it is still high in comparison with the normal value of strain rate in Japan. We may suspect, therefore, that tectonic conditions in the Nakano area are influenced by the Matsushiro swarm in some sense, directly or indirectly, to undergo crustal deformations at a relatively high rate as observed.

4) The total strain accumulated in Omachi during 1964-1966 seems to be as small as that of the order of 10^{-6}. However, the authors failed to observe it accurately because of an accident on the bench mark at the base station.

The authors acknowledge with many thanks members of the General Affairs Section of the Matsushiro Town Office, the Health Section of Nakano City Office, the General Affairs Section of Toyono Town Office and of Omachi City Office for their kind cooperations given to the abovementioned field work. Mr. Muto of the Minakami-yama Shrine and Mr. Fujimaki of the Omachi Museum supported the field work in many respects. The authors are also grateful to Messrs. Tamotsu Daikubara and Kiyoshi Suzuki of the Technical Division of this Institute for their helpful assistance during the surveys.

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12. 群発地震活動に伴う地殻変動の観測 (3)

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1. まえがき

松代群発地震に関する綜合調査の一環として，筆者らはジオデメーターによる光波測量を昨年秋以来実施している．特定の測線に対する測量を繰り返すことにより，地震活動に伴う土地の水平変動の消長を明らかにするのがその目的であって，1965 年 10 月松代に基線網を設置して以来ほぼ 1

ケ月間隔 (平均) で光波測量を繰り返してきた. 又, 地震活動が拡大するにつれて調査範囲を更に広げる必要が生じたため, 1966 年春頃には中野・若穂の両地域にも基線網を設置し観測を始めることになった. これら三地域における測量結果のうち本年9月迄に得られたものについては第1報及び第 2 報に報告してある. その後, さらに測量が追加実施され, 地震活動の経過に関係あると思われる興味深い資料が得られた. 又, この期間中に大町基線網についても測量が行われた. たまたま, 同地域には基線網が 1964 年 11 月に設置され第 1 回測量が行われていたので, 今回の測量結果と比較することにより過去 2 年間における同地域の変動状況が明らかになるものと期待されたのである. これら四地域での作業結果を以下第 3 報として報告する次第である.

2. 観　　測

松代基線　象山, 西寺尾, 可候の三基線から成る松代基線網の構造は前報に記してあるからここではあらためて述べない. 9 月の第 IX 回作業のあと, 今期には次の通りこの回の測量が行われた.

第 X 回　1966 年 10 月 13-14 日
第 XI 回　〃　11 月 12 日

第 1 表 (a) には松代基線網に対するこれら測量結果について, 必要な気象補正を加えたものを既報分とあわせて示してある. D は各測量時期における基線長であり, ΔD は第 1 回当時から通算した変動量である。第 X 回の結果について見ると, 最も変動の大きいのはやはり可候基線であって, 前回に比べればさらに 26 cm, 第 I 回から通算すれば実に 116 cm の伸張をとげたことになる, 同じく西寺尾基線では, 前回に比べて 22 cm, ΔD にすれば 72 cm の伸びが見られる. これらに対して象山基線では, 前回に比べて 3 cm, 第 1 回から通算すれば 21 cm の短縮が観測された. これを要するに, 9-10 月期の変動は従来と同じ特性をもちながら, さらに一段と進行したことが明らかである。

既に述べた通り, 地震活動は7月末以降第3活動期に入っていた. 地震発生回数は 8 月下旬頃, この活動期における最高値を記録した後, 9, 10 月には下降の一途をたどっていた. しかし竹原地区の地割れに端を発した地表変動についてみれば, むしろ 9 月に入ってから最も活発な様相が見られ, ついには相当規模の地滑りが各所に表われるに至った (関連諸報告参照). 又, 皆神山周辺で水準測量をひんぱんに繰り返した結果を見ても, 隆起変動は 9 月中旬に至る迄活発化の一途をたどっていた. 従って上記の水平変動進行経過はこれらの諸様相と調和していることになる.

10 月に比べると 11 月の測量結果は, 可候基線で −5 cm, 西寺尾基線 −2 cm, 象山基線 −1 cm, 即ちいずれも短縮した. 昨年秋以来, 前二者に沿う変動が伸張に次ぐ伸張を示してきたことと考えあわせると, これは誠に著しい様相急変と言わなければならない. 事実, これに相当する急変は水準測量や傾斜観測からも報告されており, 10 月中旬を境に地震活動に本質的な転換があったものとも想像される. この点については諸種の情報を綜合してさらに詳しい検討が要望される次第である.

若穂基線　基線網の構成については前二報で説明したからここでは省略する. 第 V 回測量は 11 月行われた. これを去る 7 月に行われた前回に比べると, 第 1 表に示す通り, 下和田基線 −19 cm, 大橋基線 −3 cm (通算 −9 cm), 温湯基線 −2 cm (通算 −3 cm), 即ちいずれも短縮する傾向を示している.

中野基線　10 月に行われた第 III 回測量結果を去る 4 月の第 II 回のそれに比べると大倉基線 −20 cm, 桜沢基線 −3 cm (通算 −5 cm), すなわちいずれも短縮している. これにひきかえ, 今井基線では著しい変化が認められず第 I 回から起算すれば 1 cm の伸張となる (観測誤差: 1〜2 cm).

大町基線　たまたま大町地域には 1964 年 11 月に基線網が設置され (第 2 図), 第 I 回の測量が行われた. これはネオテクトニクス研究計画に基ずき, 地殻変動研究上特に興味深い地域の一つとして光波測量が計画されたものである. 松代群発地震活動の広域化が案じられるに及び, 大町地方での変動の有無を明らかにしておくことも必要と思われた. 第 1 表 (d) に示す通り清水沢基線は前回に比べて −5 cm の変動(短縮)が認められた. 不幸にして, 残りの基線の測量にかかる前, 基点標石にも支障が生じたので, 他方向への変動は確認出来なくなった. 同表中鹿島大橋及び平の両

基線に対する数値は暫定的なものであって，平基線に沿う 2 年間の変動をゼロと仮定した結果である．つまり第 I 回と第 II 回とでこの基線の長さに差があるとすれば (実測では 7 cm)，それはもっぱら新標石の旧標石に対するずれ(測線方向への)によるものと見なすことにする．清水沢方向への標石のずれは復旧測量によって知られているから (8 cm)，これと組み合わせて新標石の鹿島大橋方向へのずれが推定される．この値に基ずく補正を加えた結果，同基線に沿う変動は −4 cm (短縮)となった．

3. 考　　察

松代地域の三基線に対する測量結果から算出した歪み量の時間的変化を第 3 図に示してある(昨年 10 月起算)．変動の進行を示す線は第 3 期の活動を反映して，前回に劣らぬ急傾斜を示している．特に著るしいのは可候基線で，測量開始以来正 1 ヶ年の間に 370×10^{-6} の伸張をしたことになる．地殻歪みを基線網内で均一とみなすことに再考の余地があることは前報でも述べた．しかしながら従来の測量結果と同一基準で比較する為にさし当りこの仮定をとり続けることにする．従って西寺尾基線では 250×10^{-6}，象山基線では -90×10^{-6} の歪み集積があったことになる．同図から明らかな様に 10 月から 11 月に入るに及んで変動の進行が止まり，むしろ逆行の傾向さえ見えるようになった．第 4 図は従来と同じ手続きによって歪み主軸を求めた結果であるが，(X–XI) 期間に伸張はなく一本の短縮軸で表示されている．これは上記期間に各基線とも短縮を示した事実に対応したものである．水準測量から知られるように，皆神山東北麓に沿う地割れ地帯を中心として進行してきた隆起は，10 月後半以来沈降に転じた事実が著しい．これに伴って予想される山体傾斜の方向(北々東南々西)にこの短縮軸が合致している点が興味深い．傾動が基線長にどの程度影響するかいずれ明らかにしたいところであるが，いずれにせよ，10 月迄に見られた急激な水平変動の進行が停滞しつつあることは疑問の余地がない．

若穂・中野・大町の各基線網に対する歪み量の時間的変化は第 5, 6, 7 図にそれぞれ示されている．これらの地域に対する歪み主軸の様相は次の第 8 図に総括的に示してある．

これは筆者等の測量を通じて明らかになった水平変動を，北信地方の視野で比較するため描いたものである．長軸の長さについて正規化された歪み主軸の様相を主軸値 (10^{-6} 単位)と共に示してある．かっこ内の測量時期から知られる通り，これ等変動は長短まちまちの間隔 (6 ヶ月～2 年) に対するものである点，注意を要する．

一般的に最も変動の激しいのは言うまでもなく松代地域であり，若穂・中野・大町の順序でこれに次ぐ，松代地域の変動については既に述べた通りである．若穂の主軸が伸張・短縮両軸共に松代のそれに似た方向を指していることは興味深い．これは松代を中心とする事実を暗示するものかもしれない．中野地域の歪み量は若穂もそれに比べて 1/3～1/4 の程度であるが，それでも従来筆者らが一般地域で経験した変動量に比べれば著しく高い．この異常な変動値が今回の地震活動に直接関係するものであるか否かは今後の調査に待たなければならない．特に興味深いのは，短縮軸(破線)が西北西—東南東，すなわちこの地域における褶曲構造の伸び方に直交している点である．別の調査からこのあたりの構造が地質的に極めて若いものである事は知られているが，同図に見られる歪み主軸の方向はこの造構造運動が今もなお進行していることを意味するものかもしれない．もうひとつ注目されるのは，歪みが短縮軸ばかりでなく，これに匹敵する大きさの伸張軸(実線)を伴っていることである．褶曲運動に関する二次元的模型の立場からは予想し難いところであるが，これも又今後の問題点として残しておく．大町地域の主軸は既に述べた仮定に基ずくものであるから，深く立入る事を避けたい．いずれにしても $10\cdot10^{-6}$ 程度と見られるこの地域における過去 2 年間の変動は平常時の値としては大きなものであるから，今後さらに調査を続ける必要があろう．

4. む す び

松代およびその周辺三地域で光波測量を繰り返した結果，群発地震活動に伴う水平変動の特性及びその地域性がさらに明らかになった．

(1)　松代地域の変動は 9～10 月にかけてさらに進行し，可候基線では通算 116 cm，西寺尾基線 72 cm，象山基線 −21 cm を記録した．これを頂点にして同地域の活動は 10～11 月期には

停滞又は逆行に転じた事実が明らかになった．他種の観測資料と併せ考えると，松代地域の地震活動はこの時期において大きな転換を遂げたものと推定される．

(2) 若穂地域の変動は松代のそれに比べればはるかに少いが，方位特性においてはほぼ同じ傾向にある．これは松代を中心とする水平変動の広がりが同地域まで及んでいることを暗示するものかもしれない．

(3) 中野地域の変動は更に少い．前記二地域とは方位特性が全く異り，むしろ当地域の地質構造に調和する点が興味深い．

(4) 過去 2 年間を通じての大町地域の変動はさらに小さく，$10\cdot10^{-6}$ 程度と思われる．但し今回の測量実施期間中に基点標石に支障を生じたため，一部基線についのての結果は確定的でない．

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