10. *The Cause of the Subsidence of the Earth's Surface in the Kôtô Region, Tokyo. I.*

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1. In several parts of Tokyo, namely, the districts of Kôtô, Marunouti, Kanda, Tameike Valley in Akasaka, Senzyu (northern part of Asakusa) ect., the ground was found to have subsided considerably as shown by relevellings[1].

As to the cause of these remarkable subsidences there are two alternatives, the one is crustal disturbance, as, for example, local down-warping or down-ward movement of a block or blocks of small horizontal dimensions. The other is contraction of the soil composing the surface layer to a considerable thickness.

In the latter case even were the subsidence put down to contraction of the soil, the thickness of that soil which contracts itself raises certain problems. In estimating the thickness of this soil layer, the following points are important.

In Honzyo and Hukagawa, where the subsidence was very marked, the surface of the earth's crust is covered by an Alluvial deposit, about 30 metres thick, underneath which are harder Tertiary rocks[2]. The probability is that the loosely packed Alluvial soil contracted as the result of changes either physical or chemical or both in the soil itself.

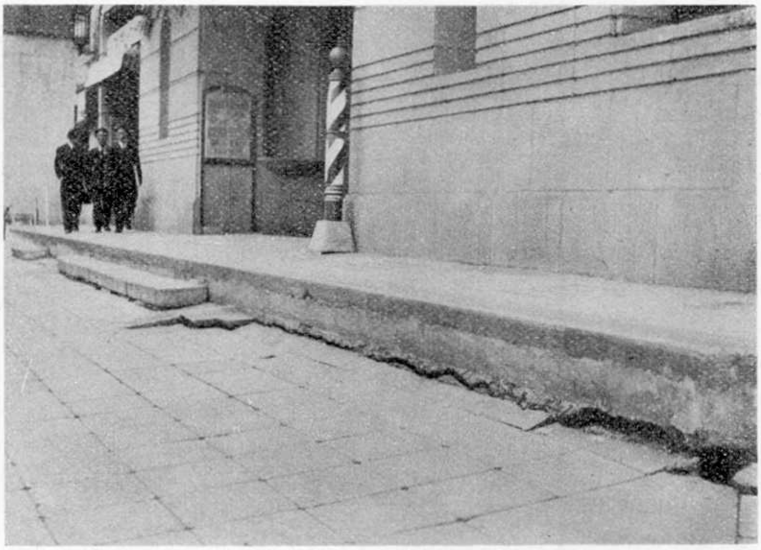
It is notable that buildings situated in the neighbourhood of Marunouti and Hibiya, in the central part of the city of Tokyo, were found to have been pushed up considerably.

These apparent uplifts of buildings can be measured easily, since, they have been pushed up in the manner shown in Fig. 1. The apparent uplifts of a number of buildings were measured in October, 1936, the results being shown in Table I. The distribution of the buildings is shown in Fig. 2, in which the bracketted numerals against the marks indicating the buildings give the amounts of apparent uplift of the

1) N. MIYABE, *Proc. Imp. Acad.*, **8** (1932), 417~420; **9** (1933), 588~591. *Bull. Earthq. Res. Inst.*, **10** (1932), 844~857; **13** (1933), 587~591; **13** (1935), 773~771.

2) Reconstraction Bureau, *Report on the Results of Geological Survey in Tokyo and Yokohama*, 1925.

respective buildings.



Fi. 1. uprise of a building.

Table I. Amounts of uprise of several buildings

Name of Buil.	Amount of Uprise	Name of Buil.	Amount of Uprise
Tokyo Marine Insurance.	14 cm	Hibiya Cine. Theatre.	4 cm ?
Syôwa	14	Kangyô Ginkô	34
Zizi-Sinpô	10	Hukoku Tyôhei	30
Tokyo Kwaikwan	18	Sisei Kwaikwan	43
Main Depo. Industr. Assoc.	44	Tokyo Dentô	78
Sansi Kwaikwan	40	Tyôsen Sôtokuhu	15 ?
Marunouti Police Office.	30	Syôkyûdô	20 ?
Sansin	40	Zinzyu Seimei.	41
Tôhô Theatre	12		

From the result obtained above, the rates of apparent uplift can be calculated for several buildings, as given in Table II.

Table II. Mean velocity of uprise of several buildings

Name of buil.	Velocity of uprise cm/year.
Tokyo Dentô	7·4
Zinzyu Seimei	5·6
Sisei Kwaikwa	5·9
Kangyô Ginkô	4·9
Tôhô Theatre	4·4
Tokyo Kwaikwan	1·2
Tokyo Marine Ins.	1·4
Syôwa	2·2
Hibiya Cine. Theatre	1·6

The rates of apparent uplift, as shown in the foregoing Table, work out to 7～4 cm per year for buildings situated in the neighbourhood of Utisaiwai-tyô, southeast of Hibiya Park.

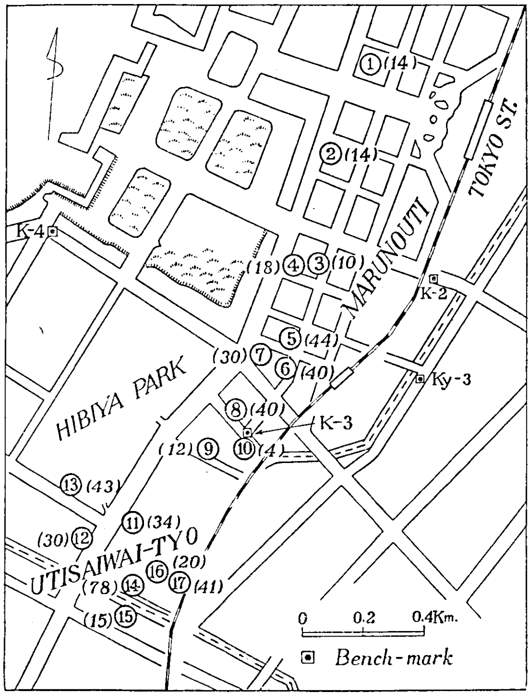


Fig. 2. Distribution of buildings, uprise of which being measured. (The bracketted numerals denote the amounts of uprise in cm)

1. Tokyo Kaizyô Hoken Kaisya Tokyo Marine-Insurance Co.)
2. Syôwa-Building.
3. Zizi-Sinpô-Sya.
4. Tokyo Kwaikwan.
5. Sangyô Kumiai Tyûô Kinko (Main Depository of Industry Assoc.)
6. Sansi-Kwaikwan.
7. Marunouti Police office.
8. Sansin-Building.
9. Tôhô (Tokyo Takaraduka) Theatre.
10. Hibiya Cinema-Theatre.
11. Kangyô Ginkô (Bank.).
12. Hukoku-Tyôhei Hoken Kaisya.
13. Sisei Kwaikwan.
14. Tokyo Dentô Kaisya.
15. Tyôsen Sôtokuhu.
16. Seikyûdô.
17. Zinzyu Seimei Hoken Kaisya (Zinzyu Life Insurance Co.)

If, as will presently be discussed, the apparent uplift of the buildings is due mainly to contraction of the soil composing the surface layer, the rates obtained above will be that of the contraction of the soil.

The foundation of most of the buildings are constructed as follows.

The ground was first excavated to a depth of several metres, and piled driven into a depth of about 20 metres. The number of piles driven is from 1 to 2 for every 4 m^2. The piles are usually concrete rods or pine logs, 20 metres long and from 10 to 20 cm in diameter.

As the thickness of the soil layer of Alluvium here is about 20 metres, these piles may reach the underlying hard Tertiary rocks, from which it may be concluded that buildings, the foundations of which are constructed as just described, are rigidly connected to the stable hard Tertiary rocks.

The apparent uprise of the buildings may therefore be regarded as due mainly to the contraction of the soil composing the surface layer and surrounding the buildings and their foundations.

These phenomena led to our constructing special bench-marks for studying the cause of the remarkable subsidence of the earth's surface in Honzyo and Hukagawa.

2. One of these special bench-marks (numbered S–1) was imbedded in the playground of the Kazuya Primary School in Hukagawa and the other (S–2) in the playground of the Kayaba Primary School in Honzyo.

They were long iron tubes, 10 cm in diameter, with a mark on the top made of stainless steel, driven to a depth of 35 metres through the soft Alluvial soil, 30 metres thick. A sectional view of the bench-mark and the soil composing the layer as obtained by boring is shown in Fig. 3.

Soon after the bench-marks were constructed, their heights relative to the nearest bench-marks were measured in April, 1936. The height of S–1 was measured relative to that of B. M. M–9831, and the height of S–2 to those of B. M.'s M–3378 and Sy–7.

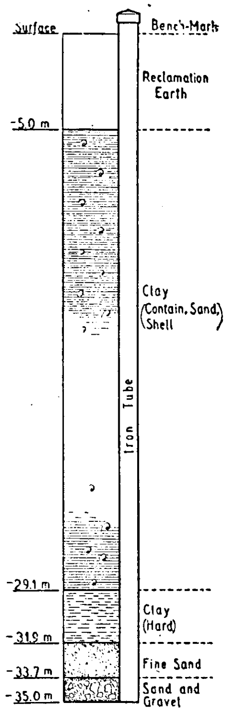


Fig. 3. Sectional view of the bore hole at Kazuya Primary School and B. M. S-1.

3. The precise levelling was revised in October, 1936, about six months after the bench-marks were established, the changes in height of B. M. S–1 relative to M–9831 and those of S–2 relative to M–3378 and Sy–7 being shown in Table III.

Table III. Heights and the changes in heights of S–1 and S–2 relative to nearest bench-marks.

Date	S1—M9831	M3378—S2	S2—Sy. 7.
	m	m	m
Oct. 1936	1·3874	−0·5352	1·3536
Apr. 1936	1·3077	−0·5692	1·3216
Change	79·7 mm	34·0 mm	32·0 mm

It may be deduced from the foregoing Table that, if the heights of the new bench-marks, S–1 and S–2, are assumed not to have changed during the interval April-October, 1936, the surface of the ground represented by the heights of B.M.'s M–9831, M–3378 and Sy–7,may be regarded as having subsided from 30 to 80 mm, relative to the surface of the Tertiary layer, which extends up to about 30 metres below the present surface of the ground.

The assumption that the heights of bench-marks S–1 and S–2 have not changed during the period mentioned is probably confirmed by the fact that the vertical displacement of B. M. M–9831 with reference to the standard datum point[3)] was found to be nearly equal to that of the same bench-mark relative to S-1 during the same period, as will be seen upon comparing Table III with Table IV, in which are shown the vertical displacements of M–9831 for various periods.

Table IV. Vertical displacements of B.M. M–9831 referred to the standard datum point.

Period	Nov.1929—Jan.1932	Jan.1935—Apr.1936	Apr.—Oct., 1936
Displacement	−156·0 mm	−282·6 mm	77·1 mm

From the facts cited above, it may be deduced that the remarkable subsidence of the surface of the earth noticed in the region of Honzyo and Hukagawa is largely due to contraction of the surface soil consisting of Alluvial deposits about 30 metres thick.

4. The relevelling of October 1936 was carried out over the line from the standard datum point to S–1 and over the line from M3378–S2–Sy7, the distribution of which is shown in Fig. 4. The vertical displacements of the bench-marks on these lines found by this relevelling are given in Table V.

Table V. Vertical displacements of bench-marks in Tokyo found by relevelling as in Oct., 1936.

Bench-mark	Displacements	Period	Bench-mark	Displacements	Period
K-4	− 10·9 mm	1929—Oct.1936	Ky-4	− 11·9 mm	1929—Oct.1936
K-3	−386·9	〃	M-J-O	− 6·4	〃
K-2	− 43·8	〃	H-1	−257·7	〃
Ky-3	−167·1	〃	R-35	−568·1	〃
R-12	− 26·6	〃	M-9831	−515·7	〃

3) Although strictly speaking, the vertical displacement of the standard datum point is not zero, it may not be sensibly large during such a short period of time as mentioned above, i. e., about six months, as estimated from the results of relevellings on the line between Tokyo and Aburatubo, where the tide gauge is constantly working. The vertical displacement of the standard datum point may therefore be ignored in the present study.

4) It will be seen that the vertical displacement, −77·1 mm, of M–9831 is approximately equal to that of the same bench-mark relative to S–1, −79·7 mm.

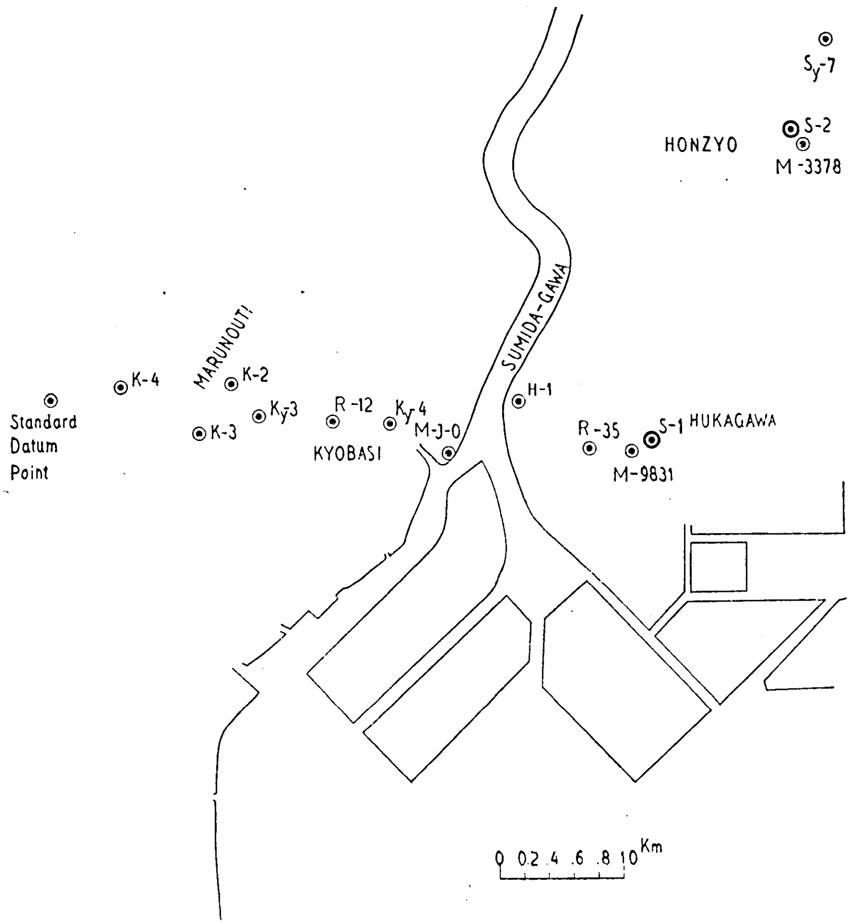


Fig. 4. Distribution of bench-marks.

As will be seen from the foregoing table, bench-mark K–3, situated very close to the Sansin-Building, sank 386·9 mm during the period from Aug., 1929 to Oct., 1936, which agrees well with the amount of apparent uprise of the building measured in October 1936. This fact seems to support the conclusion that the apparent uprise of the buildings in the neighbourhood of Marunouti and Hibiya is due to contraction of the soil composing the surface layer. It also implies that the time elapsed since the soil of the surface layer had began to contract, probably does not exceed 10 years.

Further studies of the physical properties of the soil taken from borings for bench-marks S–1 and S–2 are now proceeding so that the results will be available in due course.

The writer wishes to express his sincere thanks to the council of the Hattori Hôkôkwai for the grant of the research fund by means of which the present study was carried out. The writer's cordial thanks are also due to the Municipal Authorities of Tokyo for their courtesy in constructing the bench-marks and in carrying out the relevellings.

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10. 江東地域に於ける地盤沈下の原因に就て I.

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東京市内の一部，殊に江東地域に於いて，著しい地盤沈下の現象の認められることは既に屢〻報告された所である．

この沈下現象の原因として可能なる 2～3 の事項も既に報じておいたが，江東地域における地盤の沈下がその中の何れの事項に該當するかは未だ明かではない．

一方に於いて，種々な點から，沈下の原因が，表面に在る比較的軟弱なる地層の收縮にあるらしく思はれる．それで，先づ，表面にある地層の收縮とすれば，それが如何なる程度に沈下現象と關聯を持つかといふことを明かにする目的を以て，次の樣なことを試みてみた．

深川及び本所の地域に於いて，表面にある軟弱なる地層は大約 30 m の厚さを有することが知られてゐる．そこで，地表から約 35 m の深さに達する鐵管を埋設し，その頂部を水準標とした．鐵管の徑は約 10 cm である．若しも，沈下現象が主として表面の軟弱地層の收縮に因るものであるならば，江東地域にある他の水準點と，新に埋設した水準點との間の比高は次第に增加すべき筈である．

この水準點は，深川では數矢小學校々庭に，本所では茅場小學校々庭に埋設することを得て，其等を夫々 S-1 號及び S-2 號と名けた．この水準點の埋設をすると同時に附近の水準點との間の比高を測量したのが昭和 11 年 4 月であつた．

最近卽ち昭和 11 年 10 月其等の水準點を含む水準線に就き改測を施行した結果によると，S-1 號は附近の M-3378 號に比して 79·7 mm 上昇し，S-2 號は，M-3378 號に比して 34·0 mm，SY-7 號に比して 32·0 mm 夫々上昇したことが明かとなつた．尙，M-9831 號は同期間に於いて，陸地測量部構內に在る水準原點に比して，77·1 mm の沈下を示して居るので，これ等の結果から見ると，S-1 號水準點は，原點に比較して殆ど動かなかつた事と，從つて，M-9831 號その他の水準點によつて代表される深川附近の地表面が全體として約 80 mm 沈下した事，及びその沈下が主として表面に在る厚さ約 30 m の地層の收縮によるものであらうと思つてよいやうである．

尙，丸の內附近においても殆ど同樣の現象の存することが，例へば，三信ビルデイングの拔上り高約 40 cm と，これに程近い水準點 K-3 號の沈下量 386·9 mm とを比較することによつて知れるであらう．
