ON THE SEISMOLOGICAL ASPECTS OF THE 1954 HYDROGEN BOMB EXPLOSIONS

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Summary

Tentative conclusions previously drawn from an analysis of seismic readings of four 1954 hydrogen bomb explosions are re-examined in the light of source data subsequently released on these explosions. The released data show that the authors' earlier computed origin-times for the four explosions were correct within 0·0, 0·4, 0·7, and 0·1 sec respectively. The re-examination shows that the J.B. *P* tables need a correction of $-2 \cdot 2 \pm 1 \cdot 0$ sec for surface epicentres in the mid Pacific and recordings at continental stations. It is confirmed that any difference between the *P* travel-times from Bikini to Australia and Bikini to the United States is not much more than ½ sec. The authors' previous inferences on the velocities of air waves from the explosions remain undisturbed. The re-examination confirms the occurrence of diffracted *PKP* waves in front of the 142° caustic, and confirms that these diffracted waves arrive at times significantly earlier than *PKIKP* waves.

I. Introduction

Three papers (Burke-Gaffney and Bullen 1957 ; Bullen and Burke-Gaffney 1957, 1958), previously published on the 1954 hydrogen bomb explosions, will be referred to as papers I, II, and III. In these papers, various inferences have been drawn from seismic records of the explosions, but the inferences were all made without knowledge of data at the explosion sources. The United States Atomic Energy Commission has now released the source data, so that the reliability of the inferences can be checked. The purpose of the present paper is to carry out this check.

The officially released (G.M.T.) origin-times of the four explosions are :

(i) 1954 Feb. 28^{d} 18^{h} 45^{m} $0 \cdot 0^{s}$
(ii) 1954 Mar. 26^{d} 18^{h} 30^{m} $0 \cdot 4^{s}$
(iii) 1954 Apr. 25^{d} 18^{h} 10^{m} $0 \cdot 7^{s}$
(iv) 1954 May 4^{d} 18^{h} 10^{m} $0 \cdot 1^{s}$

These figures show our previously estimated origin-times to have been correct within an average of 0·3 sec. This is in fact the order of accuracy that we had surmised during our calculations, and the corrections needed to the origin-times are, by themselves, too small to affect any of our previous inferences.

Our original calculations, however, rested on the postulate that the centre of each of the four explosions was the same as that for the Bikini explosion of

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1946 July 24, namely, 11° 35′ N., 165° 30′ E. The officially released coordinates differ from these sufficiently to warrant our carrying out a re-calculation. The official coordinates are:

(i) 11° 41′ 27″ N., 165° 16′ 25″ E.
(ii) 11° 41′ 27″ N., 165° 16′ 23″ E.
(iii) 11° 39′ 59″ N., 165° 23′ 14″ E.
(iv) 11° 39′ 56″ N., 165° 23′ 13″ E.

As will be seen, our principal inferences are in fact well sustained in the re-calculations, but a few minor numerical changes are entailed.

Taking the above latitudes to be geographic, the corresponding geocentric direction-cosines are found to be:

(i) and (ii): −0·94732, 0·24900, 0·20136
(iii) and (iv): −0·94789, 0·24714, 0·20092.

From these direction-cosines, we recalculated the distances of the recording stations, and then using the correct origin-times obtained revised residuals in place of those given in Table 2 of paper I. The Jeffreys-Bullen tables were again used, and ellipticity corrections were applied.

II. Readings at Distances less than 120°

Table 1 below gives the results for stations at distances up to 120°. In forming this table, the arrival-time data set down in Table 1 of paper I were used with the sole exception of Baguio, for which revised readings had been set down in paper III. In Table 1, Δ_1 denotes the distance from the centres of shocks (i) and (ii), and Δ_2 from shocks (iii) and (iv).

The standard four-figure direction-cosines of observatories were used in computing Δ_1 and Δ_2, so that the calculated values may be in error up to 0°·03. The recorded arrival-times at stations were in general available only to the nearest second, but computed travel-times, ellipticity corrections, etc. were estimated to 0·1 sec in order to avoid introducing additional errors. Thus fluctuations at least up to 0·7 sec are to be expected between individual residuals in Table 1. The entries under "mean residual" relate only to *P* or *PKP* readings.

Comparison with the residuals obtained in paper I shows that the new residuals are even slightly more self-consistent than the old. The residuals remain predominantly negative and are actually numerically a little larger than those of paper I. All the broad conclusions of paper I are confirmed. The detailed conclusions are these:

(*a*) The mean residual for *P* readings at all stations up to Kiruna is −2·2±1·0 sec. This is compatible with the result −1·8±0·8 sec obtained by Bullen (1948) from readings of the 1946 Bikini explosion, and confirms the fact that, for a surface epicentre in the mid Pacific, the J.-B. *P* tables need a negative correction of more than a second for travel-times to continental stations.

(*b*) The mean residuals at Riverview, Brisbane, Pasadena, and Fayetteville have all been increased from paper I. But the mean difference between the

Australian and the United States stations remains only 0·5 sec. Thus it is confirmed that the differences in travel-times from Bikini to Australia and from Bikini to the United States differ, if at all, by not much more than a half-second.

(*c*) The four readings at Stuttgart are very consistent and indicate a correction of $-1\cdot0\pm0\cdot4$ sec to the J.-B. *PKP* table for a mid Pacific surface focus. The two readings at Tananarive do not support a need for this correction, but it is likely that the first onsets at Tananarive were too small to be recorded.

(*d*) The conclusions in paper I on the velocities of air waves from the explosions remain unaffected.

TABLE 1

P AND *PKP* RESIDUALS AT DISTANCES UP TO 120°

Station	Δ_1	Δ_2	(i) (sec)	(ii) (sec)	(iii) (sec)	(iv) (sec)	Mean Residual (sec)
Noumea ..	33°·72	33°·69	−0·4			−0·2	−0·3
Matsushiro	34°·73	34°·82	+4·3(*S*)	−1·4			−1·4
Brisbane ..	40°·71	40°·72	−1·1	−1·5	−1·9	−1·3	−1·5
Baguio ..	43°·54	43°·66	−1·6	−2·0	−3·3	−2·7	−2·4
Riverview	47°·22	47°·23	−1·7	−1·1	−1·5	−1·9	−1·5
Kaimata ..	54°·15	54°·12				−1·3	−1·3
Victoria ..	69°·01	68°·95	−4·5	−4·9		−2·3	
Pasadena	72°·46	72°·38	−1·6	−2·0	−2·0	−2·4	−2·0
Fayetteville .	91°·54	91°·47	−2·3	−1·7			−2·0
Quetta ..	91°·26	91°·37	−3·1		−2·3	−2·7	−2·7
Kiruna ..	96°·75	96°·80				−3·6	−3·6
Uppsala ..	104°·11	104°·17				+5·1	+5·1
Ksara ..	113°·94	114°·06		0 (*PP*)*			
Stuttgart	116°·19	116°·25	−1·5	−0·9	−1·3	−0·5	−1·0
Tananarive	119°·75	119°·85		+0·2		+0·4	+0·3

* If the reading at Ksara were taken as $48^m\ 42^s$ instead of $49^m\ 42^s$, the reading would agree with *PKP* with a residual of −0·1 sec.

III. READINGS IN THE RANGE $137° < \Delta < 142°$

In papers II and III, attention was drawn to what, on the calculations of paper I, appeared to be abnormally early readings at all three stations in the range $137° < \Delta < 142°$. It was suggested that the early readings related to diffracted *PKP* waves associated with the caustic at 142°. The newly released source data referred to earlier in this paper enable us to confirm this conclusion.

In Table 2 below, we give the revised results for the three stations. The distances Δ_1 and Δ_2 are given in brackets below the names of stations. For Pretoria and Kimberley, the revised residuals correspond to the readings, both first onsets and certain later phases, made by Dr. Hales and referred to in paper III. For Tamanrasset, the revised residuals correspond to the arrival-times given in paper I.

In Table 2, the means of the first arrivals at the three stations are −11·0, −8·3, −6·1 sec respectively, as against −11·1, −8·2, −6·1 sec, obtained in paper I. Means of the late arrivals at Pretoria and Kimberley are likewise much the same as before.

Thus the conclusions of paper III on the existence of diffracted *PKP* waves in front of the 142° caustic, arriving at times significantly earlier than *PKIKP* waves, are totally substantiated. The official release of the source data of the explosions has thus confirmed the importance of the explosions in adding a final link in the chain of evidence on the existence of the Earth's inner core.

TABLE 2

RESIDUALS AT STATIONS BETWEEN DISTANCES OF 137° AND 142°

Station	(i) (sec)	(ii) (sec)	(iii) (sec)	(iv) (sec)
Pretoria .. .. (137°·22, 137°·31)	—11·4, —2·9, —0·1	—11·0, +1·2		—10·6, +1·4
Kimberley .. .. (139°·45, 139°·54)	—7·8, —1·4, +1·3	—8·2, +0·8	—6·7	—10·7, +1·8
Tamanrasset .. .. (140°·40, 140°·48)	—6·2	—8·6	—5·1	—4·6

The authors would like to record the service which the United States Atomic Energy Commission has rendered to seismology in releasing the source data on the explosions here discussed. The release has enabled the previous tentative conclusions to become well-established conclusions. And the importance of controlled explosions as a means of studying the Earth's deep interior is confirmed.

IV. REFERENCES

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SPREAD-F IONOSPHERIC ECHOES AT NIGHT AT BRISBANE. IV

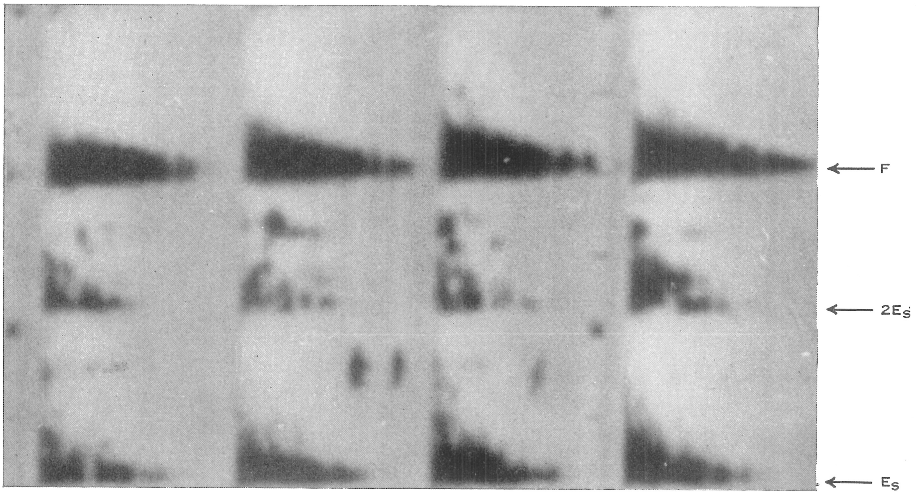


Fig. 1.—Example of swept-gain patches (March 24, 1955). Upper trace, F-region echo. Lower traces, E_s and double-hop E_s. Duration of swept-gain cycle 2 min.

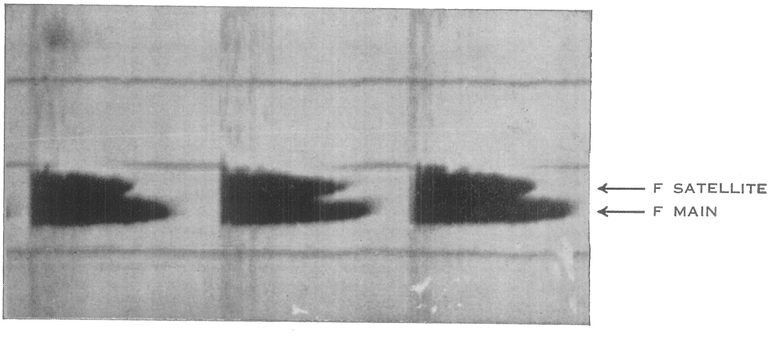
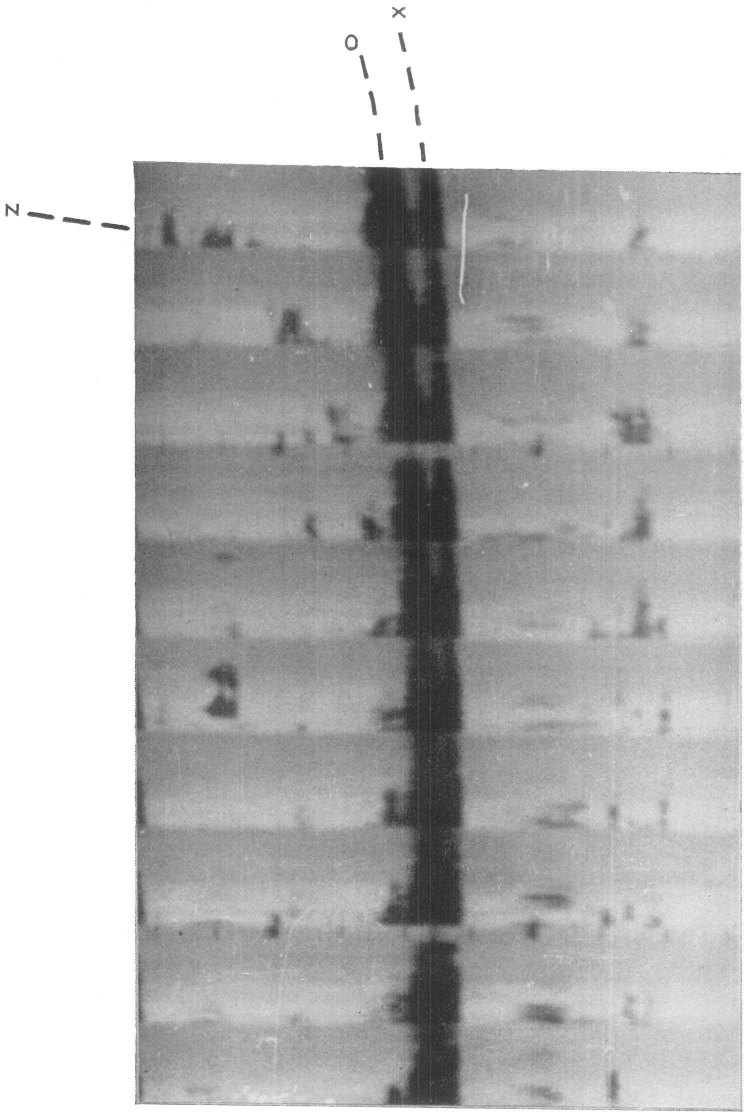


Fig. 2.—Example of swept-gain patches (December 3, 1955), showing F satellite resolved at low gain, unresolved at high (E_s not recorded on this occasion).

SPREAD-F IONOSPHERIC ECHOES AT NIGHT AT BRISBANE. IV



Example of Z-ray recorded on swept-gain $h't$ record in Brisbane, 2·28 Mc/s.