GEOPHYSICS, VOL. 40, NO. 6 (DECEMBER 1975), P. 1066–1072; 5 FIGS.

30

SHORT NOTE

SEARCH FOR GEOTHERMAL SEISMIC NOISE IN THE EAST MESA AREA, IMPERIAL VALLEY, CALIFORNIA

H. M. IYER*

INTRODUCTION

A seismic noise experiment was conducted in the East Mesa area of Imperial Valley, California, by the U.S. Geological Survey (USGS) in May 1972. There is a pronounced heat flow anomaly over the area, and between July 1972 and the present five deep test wells have been drilled over the anomaly by the U.S. Bureau of Reclamation (U.S. Bureau of Reclamation, 1974). At the time of our survey, we were aware of results from a preliminary seismic noise survey in East Mesa by Teledyne Geotech (Douze and Sorrells, 1972). A detailed noise survey was conducted by Teledyne Geotech soon after our experiment (Geothermal Staff of Teledyne Geotech, 1972). Both the Teledyne Geotech surveys show noise levels (in the 3.0 to 5.0 hz band) 12–18 db higher over the area where the thermal gradients and heat flow reach maximum values than in the surroundings. Our results, on the other hand, show that the seismic noise field in the area is dominated by cultural noise, and it is impossible to see a noise anomaly that can be related to the geothermal phenomena in East Mesa. We think that it is important to take into account this disagreement between the two results in order to make a critical evaluation of the utility of seismic noise as a geothermal prospecting tool. The purpose of this note is to put our findings on record.

EXPERIMENT AND DATA ANALYSIS

Slow-speed tape recording systems and 1 hz seismometers were used in our experiment. [For a detailed description of the experiment and data analysis, see Iyer (1972)]. Thirty-three locations were occupied in order to cover the survey area; at least 48 hours of recording was done at each location. Seventeen of the stations had three instruments arranged in the shape of an L-array with 0.3 km instrument spacing (Figure 1). Station CEN, near the site for the Mesa 6–1 well, drilled later by the U.S. Bureau of Reclamation (USBR), and station LAN, in the quietest part of the area, were operated continuously throughout the period of the experiment in order to monitor temporal variations of the regional noise.

One of the biggest problems that we encountered in the data analysis was selection of representative noise samples. There are many sources of cultural noise in the area: the heavily traveled freeway to the south, East High Line Canal and the agricultural activity to the west, and the All American Canal and the small waterfall (power drop no. 4) in the canal (Figure 1). At night noise from agricultural activity was virtually absent, but it was found that at most stations the noise levels showed large fluctuations due to freeway traffic.

Four-hour data blocks from midnight to 4 a.m. local time were digitized at 50 samples per second, and root-mean-square amplitudes were computed for every 81.92 sec (4096 points) segment. The resultant amplitude variations with time for stations CEN, ORA, RAB, BUZ, and SAG (2.5 to 6.3 km from the freeway) are shown in Figure 2. The traces show highly correlated variations of the noise levels. At station

Manuscript received by the Editor November 21, 1974; revised manuscript received April 28, 1975.

* U.S. Geological Survey, Menlo Park, Calif. 94025.

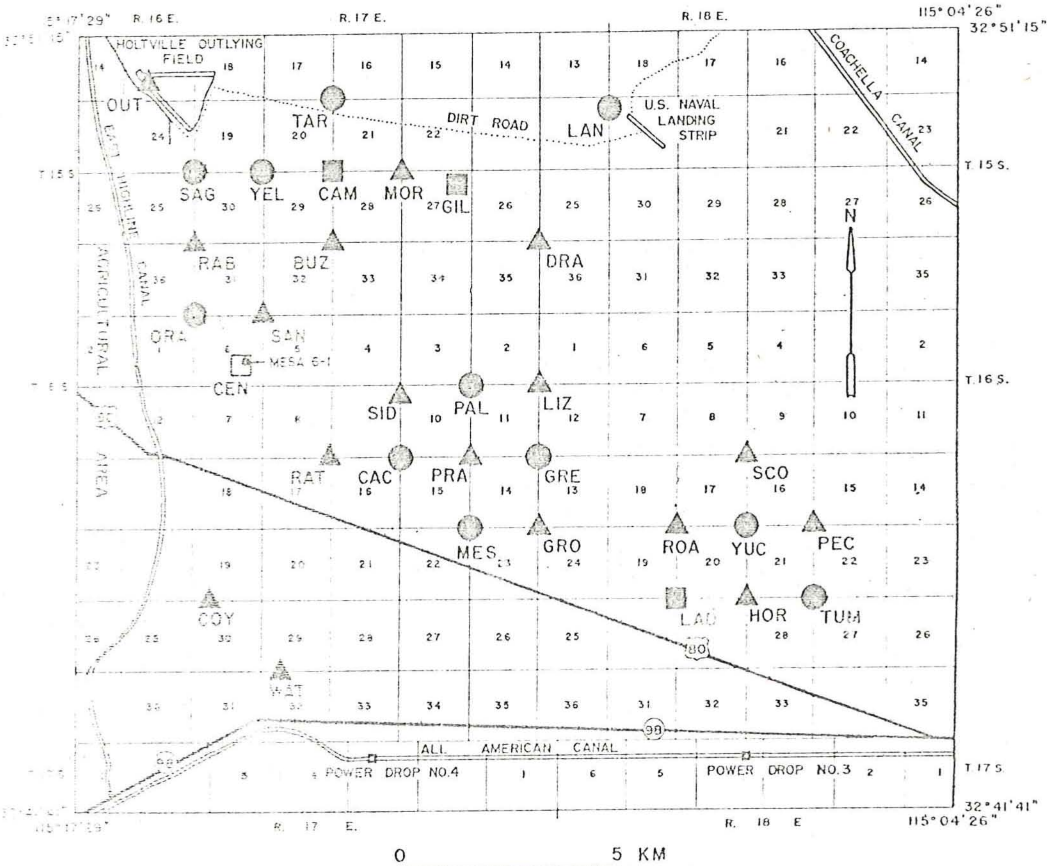

FIG. 1. Location of seismic stations occupied during the USGS noise survey in the East Mesa area of Imperial Valley. Circles locate stations with one vertical seismometer; triangles, three-component arrays; squares, three-component stations. The small numerals are section numbers. Location of the USBR (U. S. Bureau of Reclamation) test well MESA 6-1 is shown near station CEN.

CEN, 2.5 km from the freeway, the amplitude level varies by a factor of six. The variation decreases as the distance from the freeway increases. These stations form an important profile, as station CEN is located on the Mesa thermal anomaly close to where the USBR geothermal test well MESA 6–1 was drilled. It is clear from Figure 2 that it is difficult to estimate a representative background noise level at the stations where fluctuations in amplitudes are large. If the values of amplitude minima can be considered to represent such background levels, there is no indication that CEN has a higher noise level than SAG, RAB, or ORA.

Power-spectral analysis of quietest noise samples at the various stations revealed the presence of a 2.5 hz noise source. A spectral peak at this frequency can be detected at nearly all stations (Figure 3). The Geothermal Staff of Teledyne Geotech (1972) also found this noise, which was attributed to power drop no. 4 in the All American Canal. The typical noise spectra presented in Figure 3 (uncorrected for seismic system response which is almost flat from 1 to 17 hz) show a small peak around 1 hz and a broad peak between 2 and 5 hz, on which the 2.5 hz peak rides. We think the 1 hz peak is associated with oceanic microseisms (Haubrich, 1967) and the 2.5 hz peak corresponds to the preferential mode of excitation of the ground in the East Mesa area.

SPATIAL VARIATION OF NOISE

To reduce any subjective bias in sample selection, four-hour digital data blocks taken from midnight to 4 a.m. were divided into 175 con-

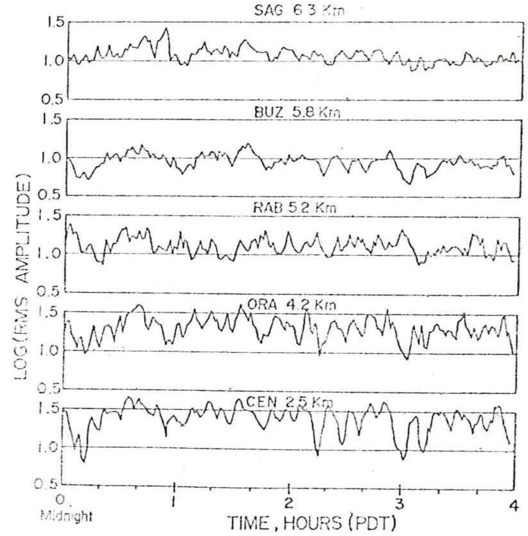

FIG. 2. Variation of seismic-noise amplitude with time at stations in the western section, at different distances from the freeway. The recording station and its distance from the freeway are shown above the frame of each graph.

tinuous segments and 20 of the quietest blocks were used for calculating average noise levels. The data were prefiltered in three frequency bands: 1 to 2 hz, 2 to 3 hz, and 3 to 5 hz, and an average rms amplitude for each band was computed. The results for the 1 to 2 hz and 3 to 5 hz bands are shown in Figure 4 as contours of spatial variation of noise power. (Spatial variation of noise in the 2 to 3 hz band shows mainly radiation from power drop no. 4 and is therefore not presented here.) Power in decibels (db) is defined as

$$P = 10 \operatorname{Log}_{10}(\bar{a})^2 = 20 \operatorname{Log}_{10}(\bar{a}),$$

where $\bar{a}$ is the average velocity amplitude of the noise in millimicrons/sec. Note that in our computation power is defined as the mean-square amplitude of the record. If a_n is the digital amplitude and N the total number of samples,

$$P = \frac{1}{N} \sum_{1}^{N} (1/2) a_n^2.$$

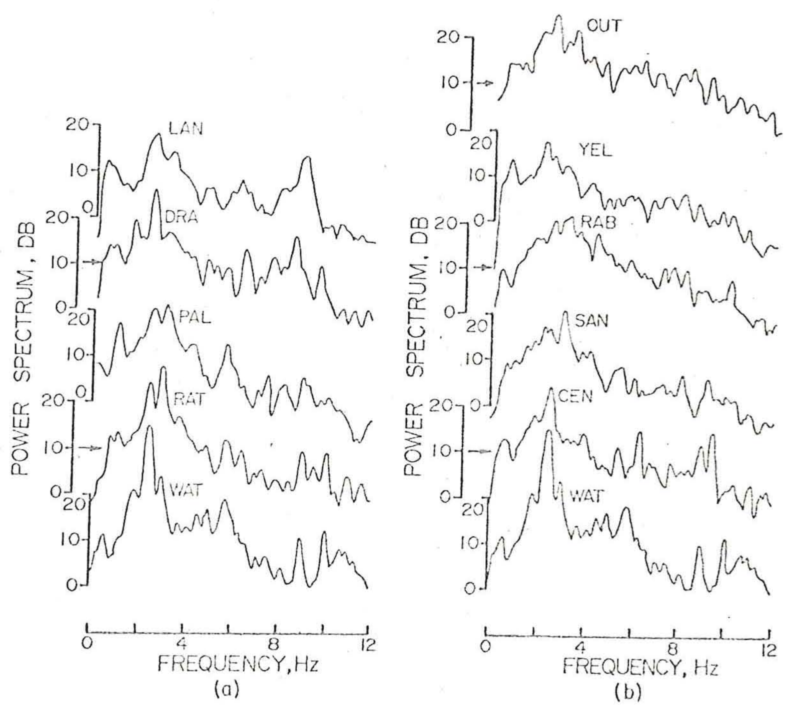

FIG. 3. Spectra of lowest levels of noise during a four-hour recording period, midnight to 4 a.m. at (a) a group of stations along an approximate northeast profile and at (b) a group of stations along the western boundary of the East Mesa area.

(a)

(b)

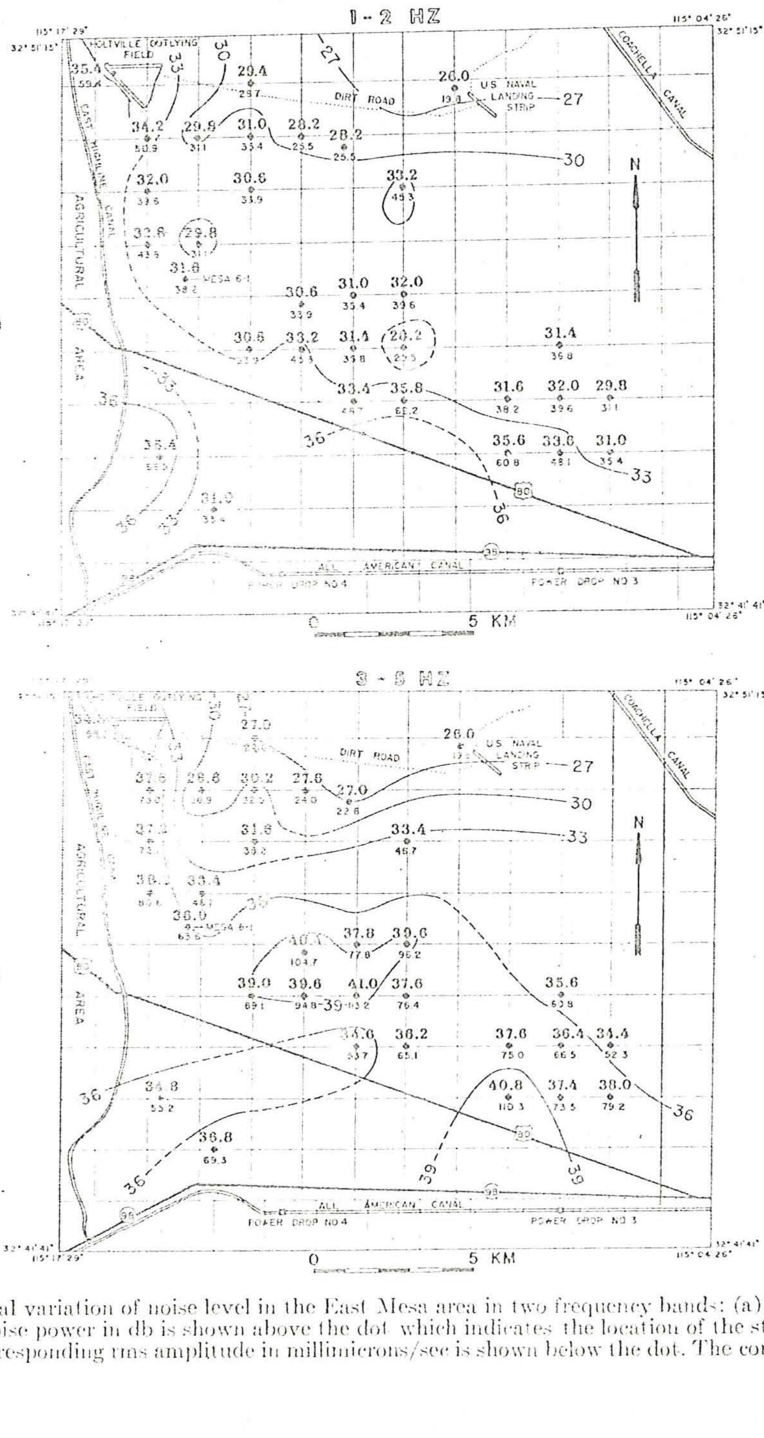

FIG. 4. Spatial variation of noise level in the East Mesa area in two frequency bands: (a) 1 to 2 hz and (b) 3 to 5 hz. Noise power in db is shown above the dot which indicates the location of the station (shown in Figure 1); corresponding rms amplitude in millimicrons/sec is shown below the dot. The contour interval is 3 db.

In the Teledyne Geotech work, power spectral estimates were made by the method described by Welch (1967). To make the two estimates comparable, 12 db has to be added to the Teledyne Geotech values.

The spatial variations of noise in the 1 to 2 hz band (Figure 4a) and 3 to 5 hz band (Figure 4b) show the same basic pattern. Noise level in the East Mesa area varies by 9 to 12 db. The quietest station is LAN, in the northeast part near the (abandoned) U.S. Naval landing strip. Highest noise levels occur along the freeway and East Highline Canal. No localized noise anomaly is seen in the area of the Mesa thermal anomaly marked by MESA 6–1 (Figure 4). Thus, we see no clear evidence for the existence of a noise anomaly associated with the Mesa thermal anomaly. If seismic noise is generated by a hydrothermal source under the anomaly, the level is clearly less than that of cultural noise in the area. Our results are significantly different from the results of Goforth et al (1972) and the Geothermal Staff of Teledyne Geotech (1972). Goforth et al (1972) show the presence of a noise anomaly of about 3-km diameter over the Mesa thermal anomaly. Results of the Geothermal Staff of Teledyne Geotech (1972) show a northeast trending noise anomaly, extending from the freeway through MESA 6–1, in the frequency bands 1 to 2 hz and 3 to 5 hz.

To make certain that we did not miss the anomaly, we analyzed data from three seismic arrays with closely spaced seismometers operated along the service road from the freeway to MESA 6–1 (Figure 5a). The average noise level in the 3 to 5 hz band, based on ten quietest samples, is plotted as a function of distance from the freeway (dots with error bars) in Figure 5b; the noise level shows no significant increase for stations near the thermal anomaly centered around station CEN. Note that the plotted average noise amplitudes measured using the arrays in the vicinity of CEN are about 12 db higher than the earlier estimates of 36 db at that station (see Figure 4b). To resolve this discrepancy, the lowest noise levels recorded by the arrays were estimated by digitally scanning the recorded data as described earlier. These values (shown within the shaded area in Figure 5b) are comparable to the noise level at CEN. If the quietest noise levels over a 3-hour

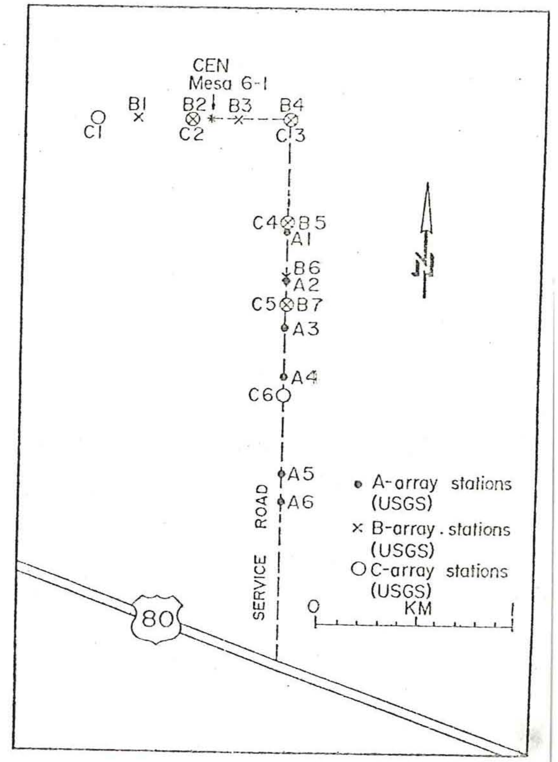

FIG. 5a. Location of instruments in the three short-term seismometer arrays operated across the Mesa thermal anomaly.

recording period can be considered to represent the best estimate that can be made of noncultural noise, we see no evidence in this plot for the existence of a noise anomaly. The results of the Geothermal Staff of Teledyne Geotech show a 9 db increase in noise level between the freeway and the peak of the thermal anomaly near MESA 6–1 (or CEN). The agreement between the USGS and Teledyne Geotech results is, therefore, poor; if a noise anomaly is present at East Mesa it is barely discernible by our experiment. We are unable to give any clear explanation for this difference in results. One source of lack of agreement is probably the ambiguities in determining average noise levels in an area where cultural noise is predominant.

MISCELLANEOUS STUDIES

We carefully searched for differences in noise spectra at various locations in the East Mesa area. As already shown (Figure 3), the shapes of the seismic noise spectra at various stations are more or less the same. Note that the spec-

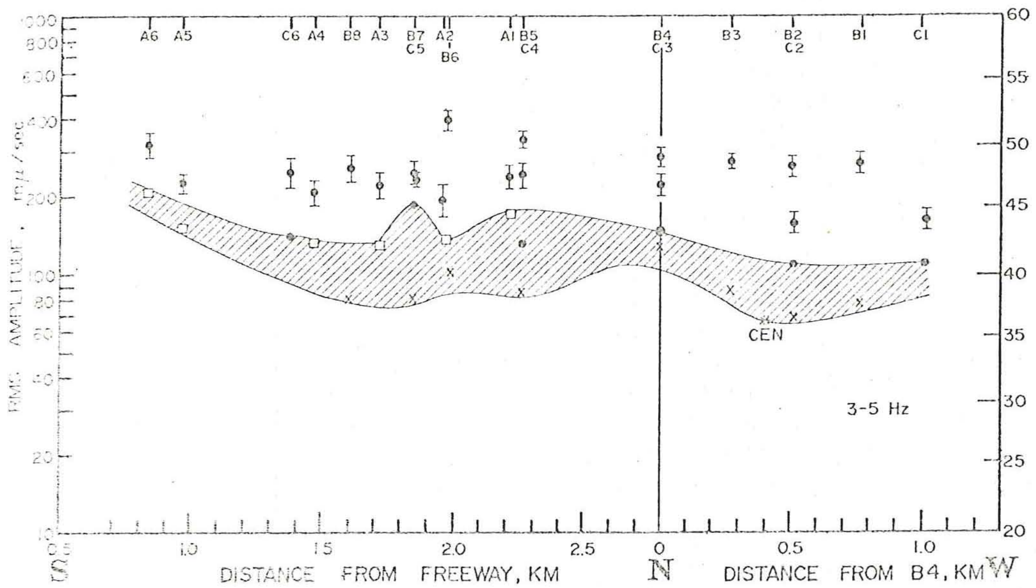

FIG. 5b. Variation of 3 to 5 hz noise along a line from the freeway to the Mesa thermal anomaly. Array station designations are shown along the top; average noise levels are indicated by dots; vertical lines through the dots represent one standard deviation. The average noise level at CEN and the lowest noise amplitudes recorded by the three arrays are shown by the various symbols in the shaded area. Squares indicate Array A stations, crosses show Array B stations, and solid circles are Array C stations.

trum at CEN, located over the peak of the thermal anomaly, is not significantly different from the spectra at other locations. Hence, we conclude that the seismic noise spectra in the East Mesa area do not reveal any information on the presence or absence of geothermal noise.

Several L-shaped arrays were operated during our experiment. Each array was made up of three vertical seismometers placed at the corners of a right-angled triangle with sides of 0.3 km. Even with such close spacing it was impossible to see any visual coherence in the array records, and this made it difficult to use the data for estimating velocity and azimuth of travel of seismic noise waves. Cross-spectral studies, however, did show some coherence, particularly at frequencies 0.4, 2.4, 3.2, and 4.4 hz. Attempts at estimating direction and velocity of wave travel from the complex cross-spectra of the array data at these frequencies were not successful. Details of these studies are described by Iyer (1972).

CONCLUSIONS

Our main conclusions are that we are unable to detect seismic noise over the Mesa thermal anomaly that cannot be attributed to cultural noise from freeway traffic or canal and agricultural activity and that the amplitude of geothermally generated noise, if present, is less than cultural noise. If the noise power of 36 db (corresponding to a velocity amplitude of 63.6 mμ/sec) at station CEN is taken to be the upper limit for the level of geothermal noise (if it exists) over the Mesa thermal anomaly, it is one to two orders of magnitude less than the large noise levels in the geyser basins of Yellowstone National Park (Iyer and Hitchcock, 1974).

ACKNOWLEDGMENTS

John Coakley, Wayne Jackson, James Gibbs, and Steven Gallanthine did the field work. Jeanne Taylor played back the tapes and digitized the data.

REFERENCES

Douze, E. J., and Sorrels, G. G., 1972, Geothermal ground-noise surveys: Geophysics, v. 37, p. 813–824.

Geothermal Staff of Teledyne Geotech, 1972, Geothermal noise survey of the East Mesa area, Imperial Valley, California: Teledyne Geotech Tech. rep. no. 72-19.

Goforth, T. T., Douze, E. J., and Sorrells, G. A., 1972, Seismic noise measurements in a geothermal area: Geophys. Prosp., v. 20, p. 76–82.

Haubrich, R. A., 1967, Microseisms, *in* International Dictionary of Geophysics: New York, Pergamon Press, v. 2, p. 975–977.

Iyer, H. M., 1972, Search for geothermal noise in the East Mesa area, Imperial Valley, California: USGS Open file rep. no. 74-96.

Iyer, H. M., and Hitchcock, T., 1974, Seismic noise measurements in Yellowstone National Park: Geophysics, v. 39, p. 389-400.

U.S. Bureau of Reclamation, 1974, Geothermal resource investigations, East Mesa test site, Imperial Valley, California: Status rep.

Welch, P. D., 1967, The use of fast Fourier transform for the estimation of power spectra: IEEE Trans. Audio and Electroacousitics, AU-15, p. 70–73.