A NEW RETRIEVAL SYSTEM OF APOLLO LUNAR SEISMIC DATA WITH DATA CORRECTION.

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Introduction: The Apollo lunar seismic data have played a significant role in lunar geophysics during the forty years since the acquisition of the data from six seismic sations at the Apollo 11, 12, 14, 15, 16 and 17 landing sites from July 1969 to Sept. 1977. Even now, lunar scientists continue to derive critical results about the structure of the lunar interior and seismic activities using these data (e.g., [1]).

However, the users often find it difficult to obtain these data for their analysis because at present not all archived data are publicly available with a convinient interface. To alleviate this difficulty, we have developed a new online retrieval system for the Apollo seismic data that enables the user to obtain the data as well as metadata necessary to use them properly. We have also found that the Apollo seismic data often contain irregularities. Some parts of the digital data were not recorded properly in the original archived files and thus we need to correct the data before using them for analysis.

In this presentation, we will report on a new retrieval system, including how the data are arhcived as well as a relational database consisting of the decoded lunar seismic data and an application to allow an online access of the database. We will then describe corrections to the Apollo seismic data and future prospects for this retrieval system. Fig. 1 shows a schematic of how the retrieval system is constructed. The retrival system can be accessed from: http://darts.jaxa.jp/planet/apollo/index.html.

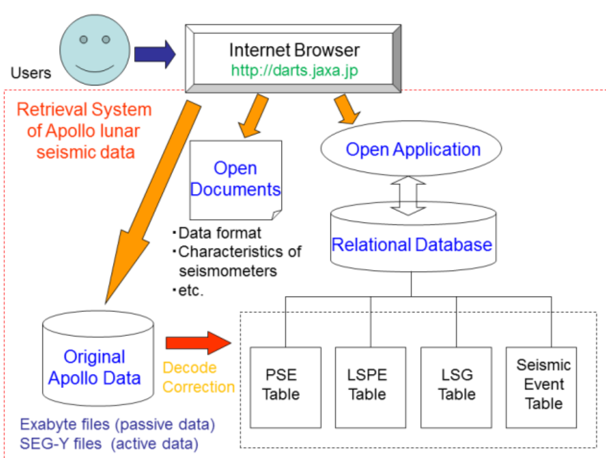

Fig. 1 Construction of the retrieval system

Archiving the Data: To construct the retrieval system, we first collected most of the Apollo lunar seismic data and information required to analyze them. We have collected all the Passive Seismic Experiment (PSE) [2] data, all the Active Seismic Experiment (ASE) [3] data, and a part of the Lunar Seismic Profiling Experiment (LSPE) [4] data. LSPE includes two types of data, passive and active, obtained by a geophone array deployed at the Apollo 17 site. We have all the active LSPE data, but passive data obtained during several time periods of a few days each from 1973 to 1975 covering a full lunation are currently missing. We have also archived the Lunar Surface Gravimeter (LSG) [5] data acquired from March 1976 to Sept. 1977. A recent analysis has indicated that some lunar seismic events are recorded on LSG with S/N ratio good enough for analysis [6].

These data are archived both in the original binary format and in decoded ASCII format in our retrieval system (Fig. 1). The binary data for PSE, passive LSPE and LSG were from Exabyte (8mm video cassette) tapes [7], and the binary ASE data are recorded in SEG-Y format. The Exabyte tapes were created in the University of Texas at Galveston during the early 1990s, and the ASE data were extracted from the Apollo scientific data archived at the National Space Science Data Center (NSSDC) and reformatted from original format by Dr. Brzostowski [8]. Since the Exabyte tape format is unfamiliar to most seismologists, we have reproduced the format information in our system. The users can download the seismic data in the original binary formats from the system and decode them by themselves using this information.

We often need to know the characteristics of the seismic sensors and the recorders to analyze the data. This information is scattered among some papers and documents, and not well organized. We have collected this information for all types of Apollo seismometers and recorders, PSE, ASE, LSPE and LSG, and summarized them in our system. The user can obtain the information from our system (Fig. 1).

Database and Application: We have constructed a relational database consisting of the decoded passive seismic data using PostgreSQL. The database is consisted of four data tables: PSE, LSPE, LSG and a table of lunar seismic events (Fig. 1). The specification of the database is listed in Table 1.

Table 1. Specification of the database system of Apollo lunar seimic data

RDBMS	PostgreSQL 8.4.7(*)
OS of DB system	CentOS 5.6 (Linux)
Maximum number of rows	1.38billions
Footprint Size	545GB
DB Tables	PSE, LSPE, LSG, seismic events

(*)This version is applied during development

The LSPE table includes only passive seismic data. The event table is created based on the 'Passive seismic experiment long-period event catalog' [9]. The catalog includes information on all the lunar seismic events identified from the seismic signals observed by the PSE long-period seismometers. One can retrieve the event types, origin times, and locations (when available) from the event tables. The PSE, LSPE and LSG tables include the clock time (time stamp) in each data frame. The seismic data of catloged events can be extracted through the PSE, LSPE and LSG tables referring to the origin times and the time stamps in our database.

We have also created an open application to access the database online using a JAVA-Script (Fig. 1). Using this application, the user can obtain the passive seismic data by visually selecting the start time of the data and sensor types. The seismic data can be downloaded in ASCII format with 'CSV' files. One can utilize these ASCII data, skipping the process of decoding the original binary files. Although the active seismic data (ASE and active LSPE data) are not included in the database due to their small volumes, the users can also obtain those data in ASCII format from our retrieval system.

Data Correction: We need to apply two types of corrections to the Apollo seismic data: signal correction and time correction.

Signal correction: In PSE, two types of seismometers, long-period (LP) and short-period (SP), were used. The SP data were acquired at a nominal sample rate of 53 samples/s and 32 samples per 603.77-ms data frame. However, two or three samples, depending on the station, were not recorded in each data frame because their places on the data frame were assigned to other scientific data. Thus, to provide an evenly spaced SP data, we need to recover these missing SP data. For this correction, we applied a 4^{th}-degree Lagrangean interpolation to all the SP data. In our ASCII database, all the SP data have thus been corrected.

Time correction: A serious timing error in the active LSPE data has recently been reported [10]. This error was caused by the use of inaccurate time stamps generated by software at the NASA Johnson Space Center. The inaccurate time stamps caused an incorrect interpretation of the data for the lunar shallow structure at the Apollo 17 landing site. This error also affects other Apollo experimental data.

We are currently performing corrections to these timing errors for the PSE data. If these errors happened around times of lunar seismic events, they are likely to cause discrepancies in data interpretation, such as incorrect locations of the events and structures. We will report a current status of these corrections in this presenstation.

Future prospects: We also plan to prepare the data files in other formats such as SEED and/or SAC in our retrieval system. These formats are familiar to many seismologists, and thus more researchers may utilize these lunar seismic data.

After the data correction for the seismic data, we hope to work on other Apollo geophysical data, including the heat-flow and magnetometer data and recent Kaguya gravity data [11], and analyze them with the seismic data. A joint analysis of the corrected seismic data with recent gravity data will improve our knowledge of the lunar interior. We expect that many users will utilize Apollo seismic data through this retrieval system for a further progrees of the planetary seismology and lunar science.

References: [1] R. F. Garcia et al. (2011) *PEPI, 188*, 96-113. [2] G. Latham et al. (1970) *Apollo12 Prelim. Sci. Rept., NASA SP-214*, 39-53. [3] M. R. Cooper et al. (1974) *Rev. Geophy. Sp. Sci., 12*, 291-308. [4] R. L. Kovach et al. (1973) *Apollo 17 Prelim. Sci. Rept., NASA SP-330*, 10.1-12. [5] J. J. Giganti et al. (1973) *Apollo 17 Prelim. Sci. Rept., NASA SP-330*, 12.1-4. [6] T. Kawamura et al. (2010) *LPS XXXXI,* Abstract#1766. [7] Y. Nakamura (1992) *UTIG Tech. Rept. No. 118*. [8] M. Brzostowski and A. Brzostowski (2009) *The Leading Edge, 28*, 414-416. [9] Y. Nakamura et al. (2008) *Galveston Geophysics Laboratory Contribution No.491*, rev.ed. [10] Y. Nakamura (2011) *JGR, 116*, E12005. [11] K. Matsumoto (2010) *JGR, 115*, E06007.