Introduction: The Near Earth Asteroid Rendezvous (NEAR-Shoemaker) mission was launched on February 17, 1996 on a planned cruise to the near-Earth asteroid 433 Eros [1]. On February 12, 2000 the NEAR spacecraft went into orbit around Eros. The spacecraft returned data from a 35 km circular orbit from December 13, 2000 to February 12, 2001. Following the landing of the spacecraft on the surface of Eros, the gamma ray spectrometer was turned on and accumulated data for approximately 14 days on the surface.

Gamma-ray photons in the energy range of 0.1-10 MeV are emitted by excited nuclei and have discrete energies characteristic of specific elements. The excitation of nuclei can come from the radioactive decay of long-lived radioisotopes or by interactions due to cosmic-ray particles. Gamma-rays emitted in planetary materials can be scattered or absorbed on a distance scale of 10-30 g/cm². Thus, only gamma rays emitted in the top 10-30 g/cm² of material (typically 4-10 cm) can be detected, but the gamma rays detected are characteristic of the bulk composition in that 10-30 g/cm² of material. This is the only remote sensing technique that can sample composition to significant depths.

NEAR Gamma-ray Spectrometer: The NEAR Gamma-ray Spectrometer (GRS) is a 2.5 cm diameter X 7.6 cm long NaI crystal. It is surrounded on the sides and back by a Bismuth Germanate (BGO) shield, approximately 2.5 cm thick. The BGO acts to reduce the gamma rays coming from the spacecraft, as a charged particle shield, and to reduce the Compton background. Five gamma-ray spectra are collected simultaneously: the raw NaI spectrum, the raw BGO spectrum, the NaI spectrum in anticoincidence with the BGO shield, and two NaI spectra collected in coincidence with 511 keV or 1022 keV in the BGO. These two spectra allow the collection of the escape spectra that are vetoed in the anticoincidence spectra [2][3].

The gamma-ray fluxes from the asteroid were expected to be low and many days of accumulation would be necessary to obtain useful spectra [3].

GRS Surface Results: At the end of the one year orbit of NEAR around Eros, it was decided to attempt a controlled decent to the surface of the asteroid. The principal goal was to obtain extremely high resolution images of the surface as the spacecraft descended. After the dramatic descent to the surface, the communications temporarily ceased, but indications were that the spacecraft had survived the landing. NASA decided to extend the mission for another two weeks and allow the GRS to accumulate data while sitting on the surface. Subsequent analysis indicated that the spacecraft landed within the 9 km depression named Himeros [4] and that the GRS was pointed toward the surface, about 18 degrees from the normal to the surface. Gamma-ray data were collected over the next two weeks and transmitted at an extremely low data rate back to the Earth.

In order to determine composition from the GRS data three steps are necessary: (1) analysis of the spectra to determine peak areas, (2) conversion of the peak areas to photons using the efficiency of the detector, and (3) conversion of the photons to composition using calculations of gamma-ray production for different compositions. Each of these steps was carried out for the surface data and results for the ratios Fe/O, Fe/Si, Mg/Si, and for Fe were reported in [5].

The findings of a chondritic composition for the GRS derived Mg/Si and K values were in close agreement with compositions derived from the XRS experiment [6]. However, the GRS derived Fe/O and Fe/Si values did not agree with most of the chondrite values; specifically the Fe abundance was low by about a factor of two. Three possible explanations for the apparent Fe depletion were considered in [5]. Among these, the most likely concerned physical processes within the asteroid regolith that might cause metal migration at the landing site and explain the discrepancy between the GRS and XRS results.

Analysis of Orbital Data: Orbital data taken prior to the landing has been difficult to analyze. The surface data represents only the composition at a particular point on the asteroid, the analysis of the
orbital data, both from the central detector and from
the shield, could be very important in understanding
the overall asteroid composition and the relationship
of GRS results to the results from other instruments.
For example, GRS orbital results can be used to
compare the elemental composition of the landing site
with the composition for the rest of the asteroid and
those derived from the XRS, NIS, and MSI
experiments [7].

Spectra taken during the 35 km orbit in December
2000 and January 2001 represent an accumulation time
of about 24 days. Background spectra taken during
the 200 km orbit in November and December, 2000
represent about 17 days accumulation. The
difference between the three types of NaI spectra, in
each case, contain little structure that would indicate
strong gamma-ray peaks. Gamma-ray lines that
should be the strongest from the asteroid, such as
the 6129 keV line from oxygen, do not show up in the
difference spectra [5]. This seems to indicate that
these spectra, whether near or far from the asteroid,
are dominated by the background signals generated
in the detector itself, the local material and the
spacecraft [8].

Several aspects of further data analysis for these
orbital measurements are being considered. It is
possible that refinements on data accumulation by,
for example, summing spectra with the same galactic
cosmic-ray fluxes before comparisons from both the
35 km and 200 km orbital data may be productive. A
more systematic analysis of the 200 km orbit data to
understand the background signals could improve
our understanding of the 35 km orbital data. Little
analysis of the orbital BGO shield data has been
carried out. While the BGO has poorer energy
resolution than the NaI, it has much larger area and a
much higher flux from the asteroid.

The evidence of an Fe depletion derived from the
GRS surface data might show some inhomogeneity in
the asteroid that can be mapped from orbit using the
landing site as a reference point. It may be possible
to derive, at a minimum, an Fe/O ratio from the orbital
spectra from both the NaI and BGO as a function of
position on the asteroid from either a change in the
count rates in two appropriate energy windows or
from a spectral analysis of the data.

The GRS derived composition results for Eros
based on the surface measurements are interesting in
that some of them are consistent with chondritic
compositions and some are not. Analysis of the GRS
orbital data to derive elemental composition would be
valuable in comparing the surface results to that for
the whole asteroid. This analysis is expected to be
complicated and entail a substantial amount of further
work.

References: [1] Cheng et al. (1997), JGR, 102,
Nittler et al. (2001) Meteoritics & Plan. Sci., 36 1673-