

EMP Theoretical Notes

Note XVII

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Prompt Gamma Ray Fluxes
and Energy Deposition in an
Exponential Atmosphere

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Abstract

The two primary factors determining gamma ray fluxes and energy deposition, attenuation by $1/R^2$ of the photons moving away from the burst point, and variations in the atmospheric density, are combined in a numeric solution to plot contours of equal energy deposition and equal fluxes in the upper atmosphere.



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I. Introduction

Beyond several kilometers above the earth primarily two factors determine the flux and energy deposition of prompt gamma rays from nuclear explosions. One is the exponential atmosphere, whose density ranges from less than a scale height to many scale heights per mean free path of a gamma ray (one scale height ≈ 7.2 km). The other is the location in space of the explosion, which by a $1/R^2$ relationship determines the maximum number of photons which could be available. Other considerations are the energy spectrum and transport of secondary photons.

II. Energy Flux and Deposition

The time independent flux for mono-energetic γ rays after attenuating through R meters of air is given by¹

$$\begin{aligned} f &= \frac{E_{\gamma}}{4\pi R^2} \exp \left\{ - \int_0^R \frac{dr}{\lambda_{\gamma}} \right\} \\ &= \frac{E_{\gamma}}{4\pi R^2} \exp \left\{ - \sigma_{\gamma} \int_0^R N_A dr \right\} \end{aligned}$$

E_{γ} : Total energy output in gamma-Mev

λ_{γ} : Mean free path of gamma ray.

σ_{γ} : Collision cross section of gamma ray

N_A : Density of air

Similarly the energy deposition is

$$E_d = \frac{E_{\gamma} \sigma_{\gamma} N_A}{4\pi R^2} \exp \left\{ - \sigma_{\gamma} \int_0^R N_A dr \right\}$$

¹Detection of the Electromagnetic Radiation from Nuclear Explosions in Space, W. J. Karzas and Richard Latter, RM-4306, Oct 64.

The photons are transported by energy groups of an initially hardened Maienschein spectrum which is further hardened by penetration through the atmosphere. For this report it is sufficient to consider all the energy deposition occurring at the point of first collisions and to neglect energy transport by scattered photons. The integration of air density (N_A) is performed numerically using an exponential atmosphere with consideration of the earth's curvature.

III. Exponential Atmosphere

The exponential atmosphere is fitted from U. S. Standard Atmosphere, 1962 and consists of a series of exponential fits between 26 altitudes up to 330 Km. See figure 1.

IV. Summary

The following plots are designed to give the general form of energy flux and deposition contours and to provide order-of-magnitude values as a function of burst altitude and spacial location. Energy deposition has been converted from electron volts to density of secondary electrons² for convenience in calculating conductivity. All the curves are normalized to one γ -Mev output. Arrows on figures 4, 6, 8, 10, and 12 indicate the horizontal extent of the 10^{-14} contour.

²Secondary electrons are produced at a rate of one secondary electron per 34 ev's deposited when the high energy compton electrons suffer inelastic collisions with air molecules.

Fig. 1

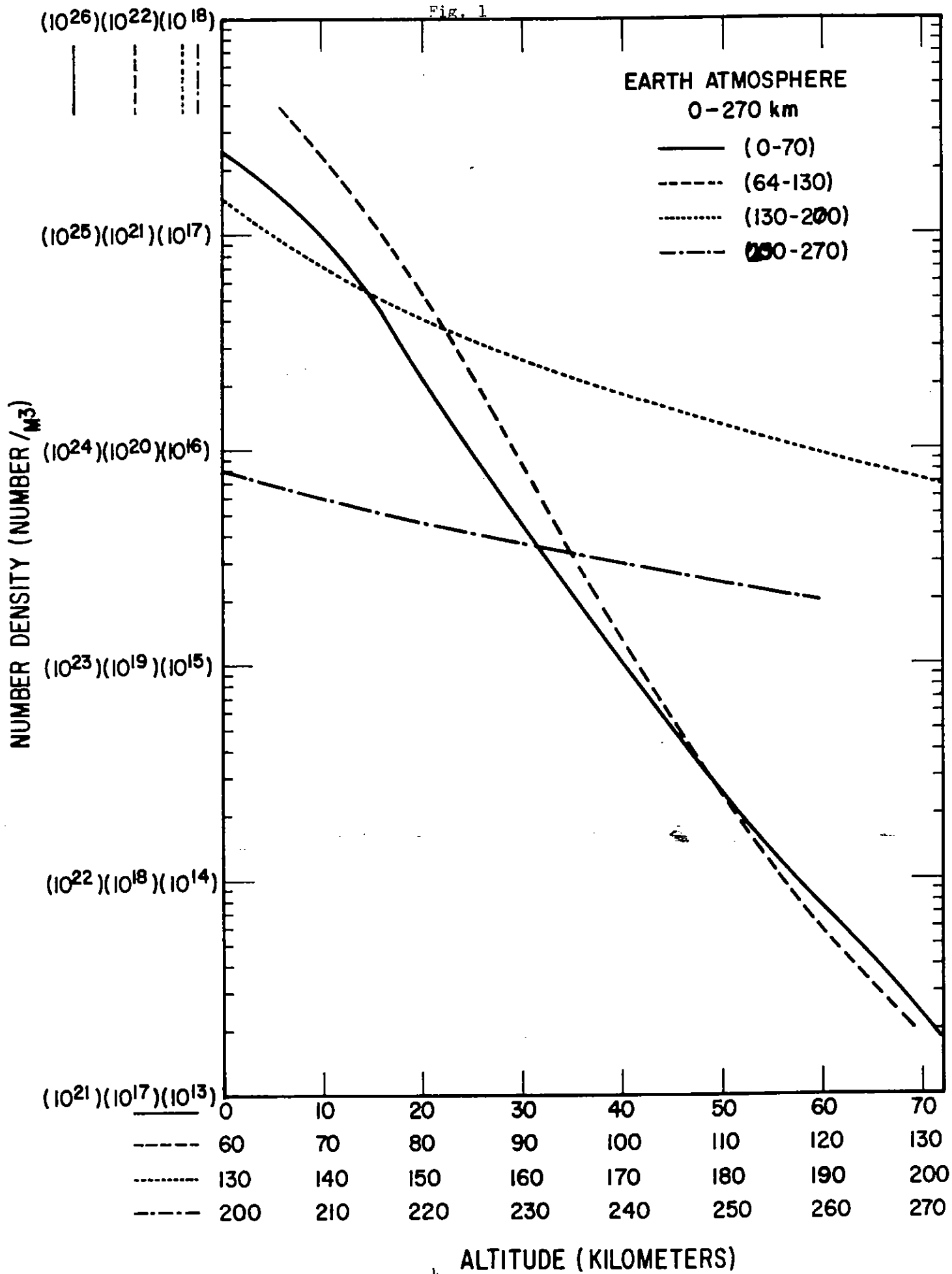


Fig. 2

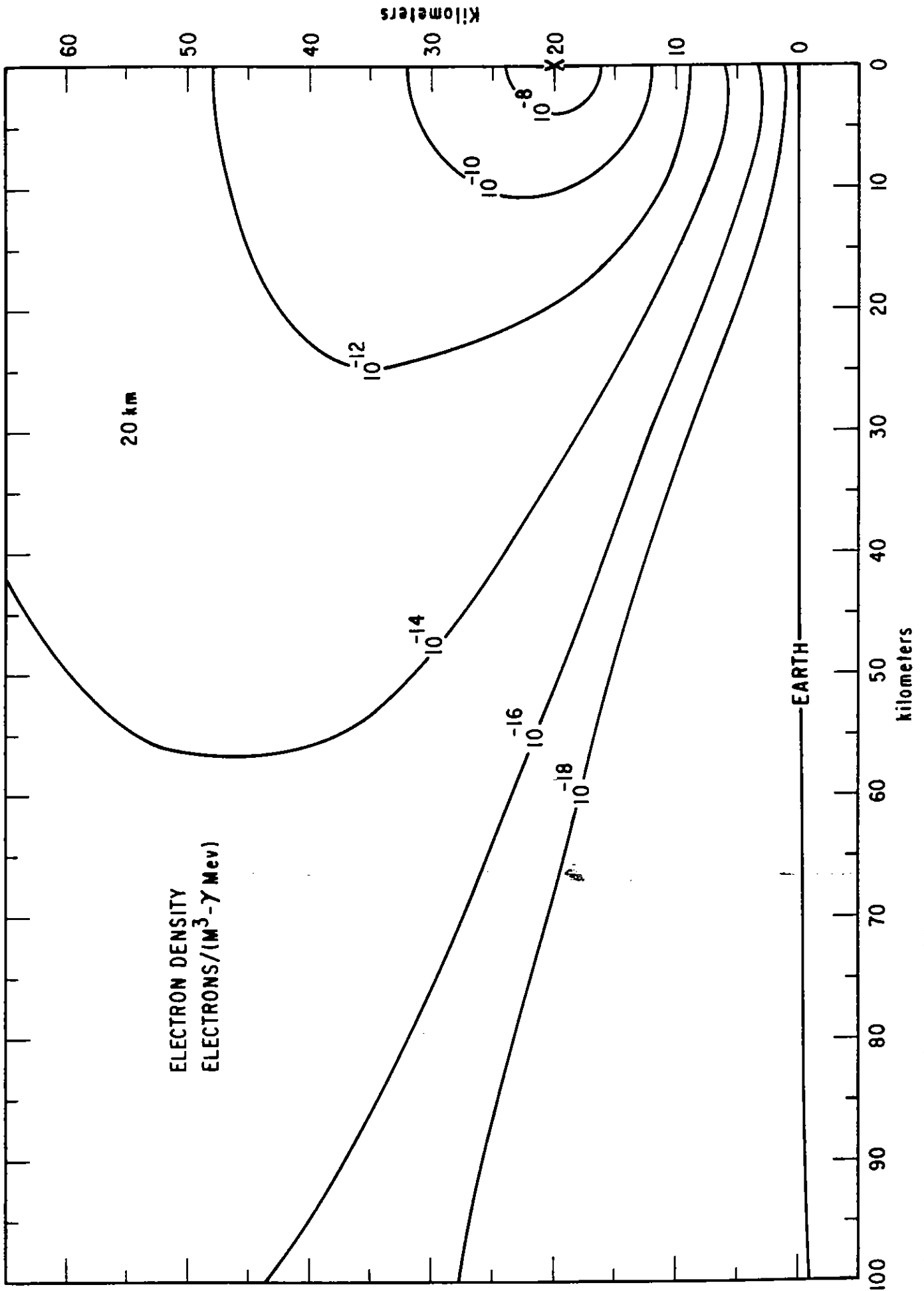


Fig. 3

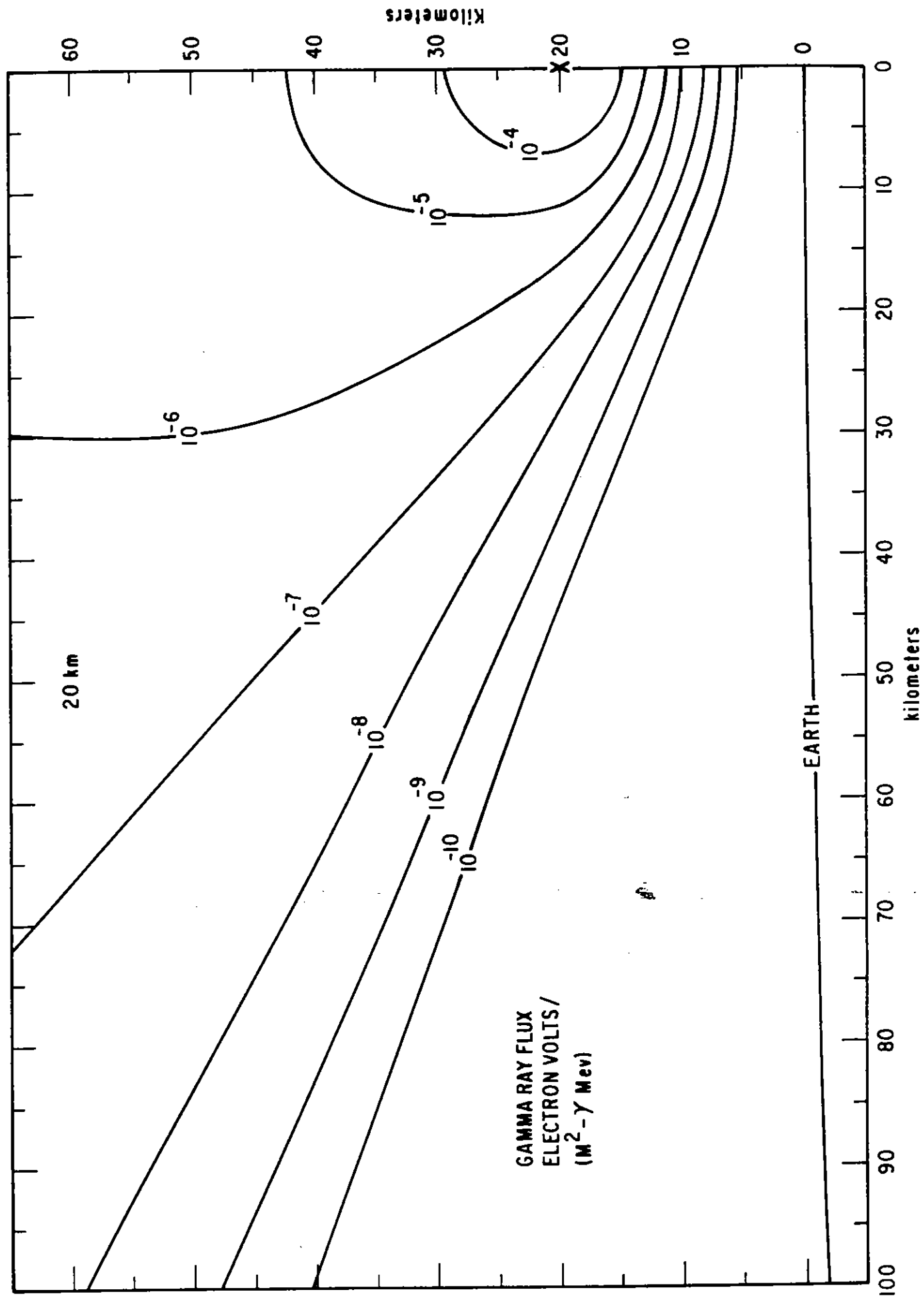
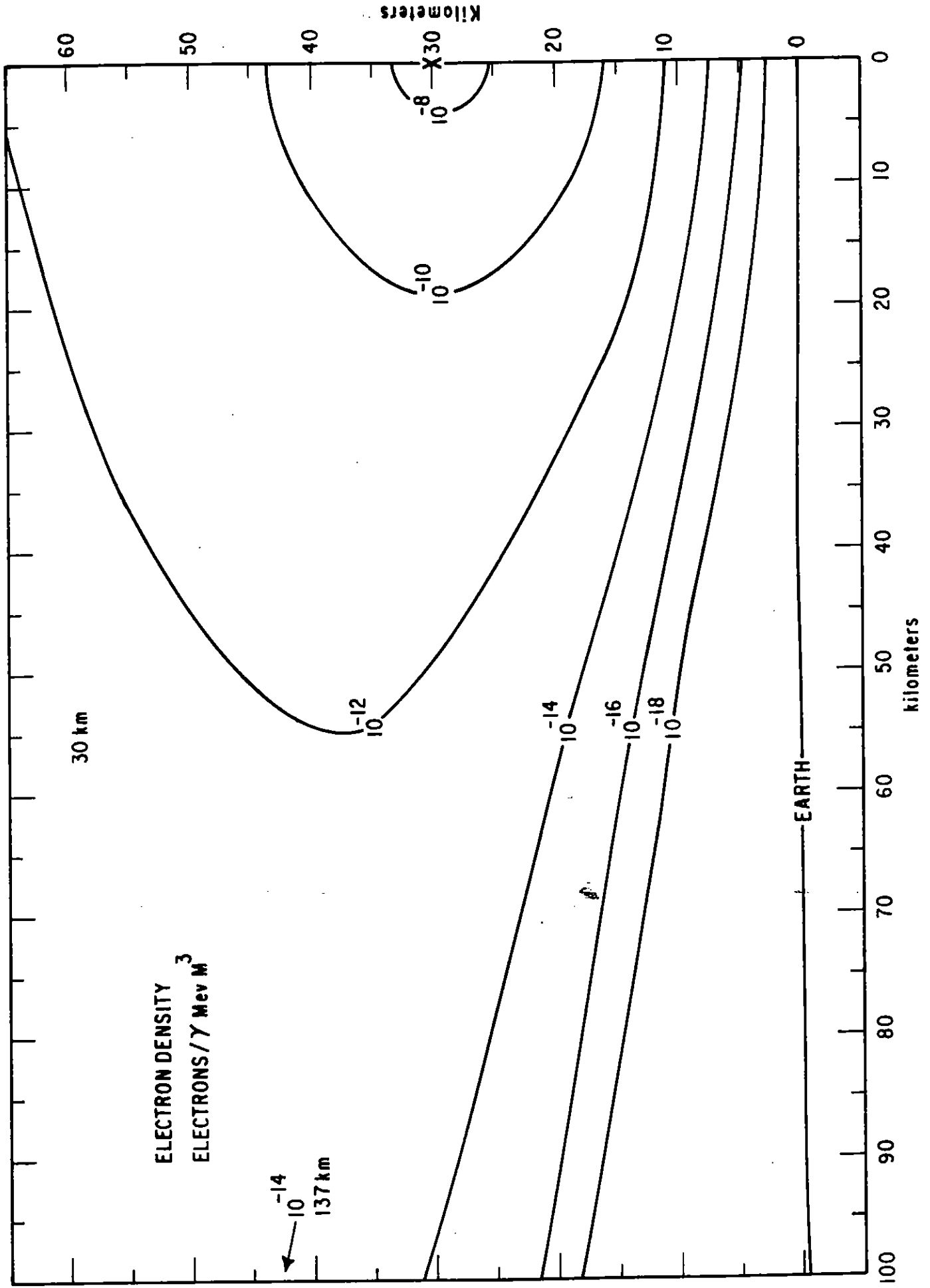


Fig. 1



ELECTRON DENSITY
ELECTRONS / Mev M³

30 km

-14
10
137 km

Kilometers

-8
10
 $\times 30$

-10
10

-12
10

-14
10

-16
10

-18
10

EARTH

kilometers

Fig. 5

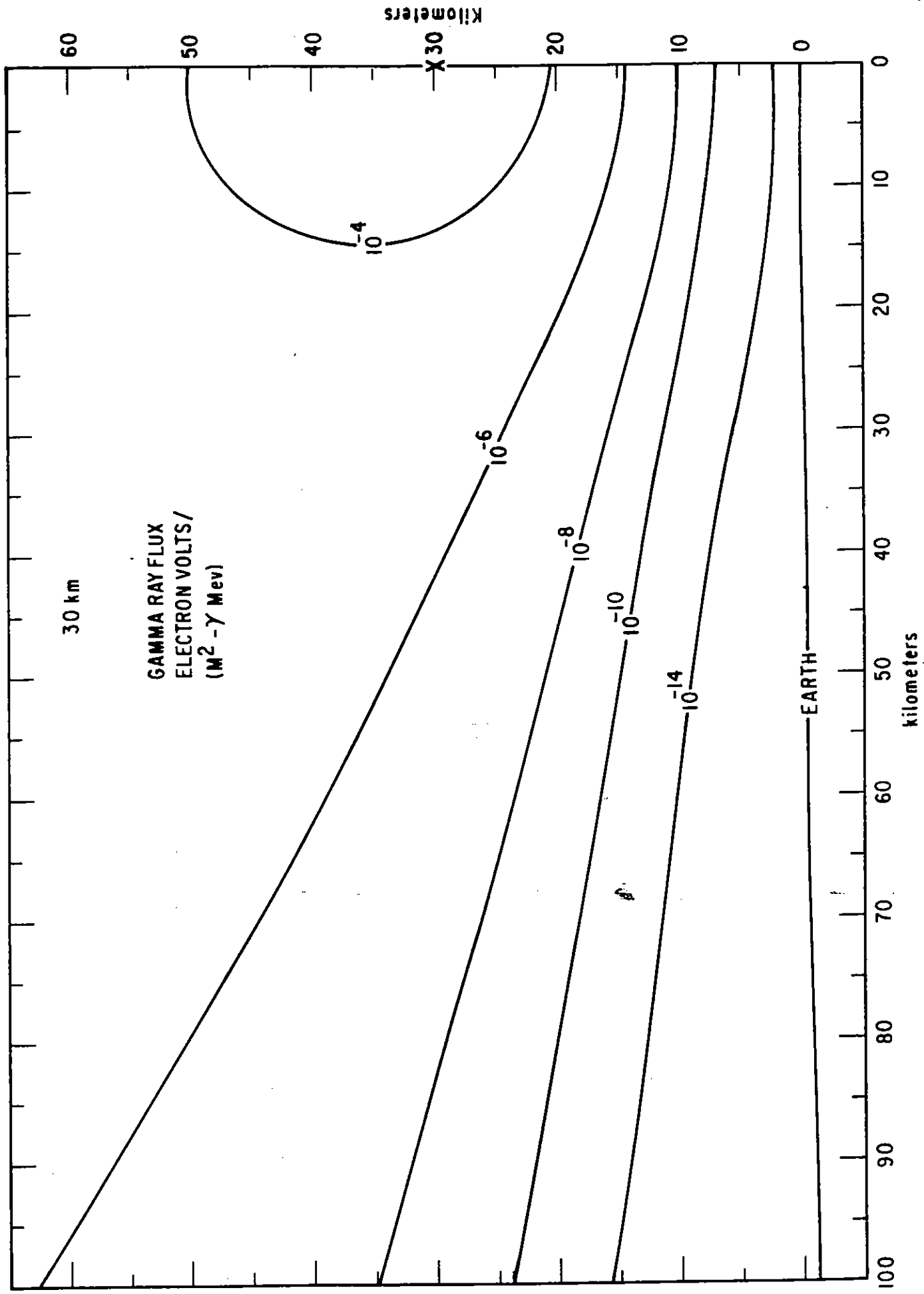


Fig. 6

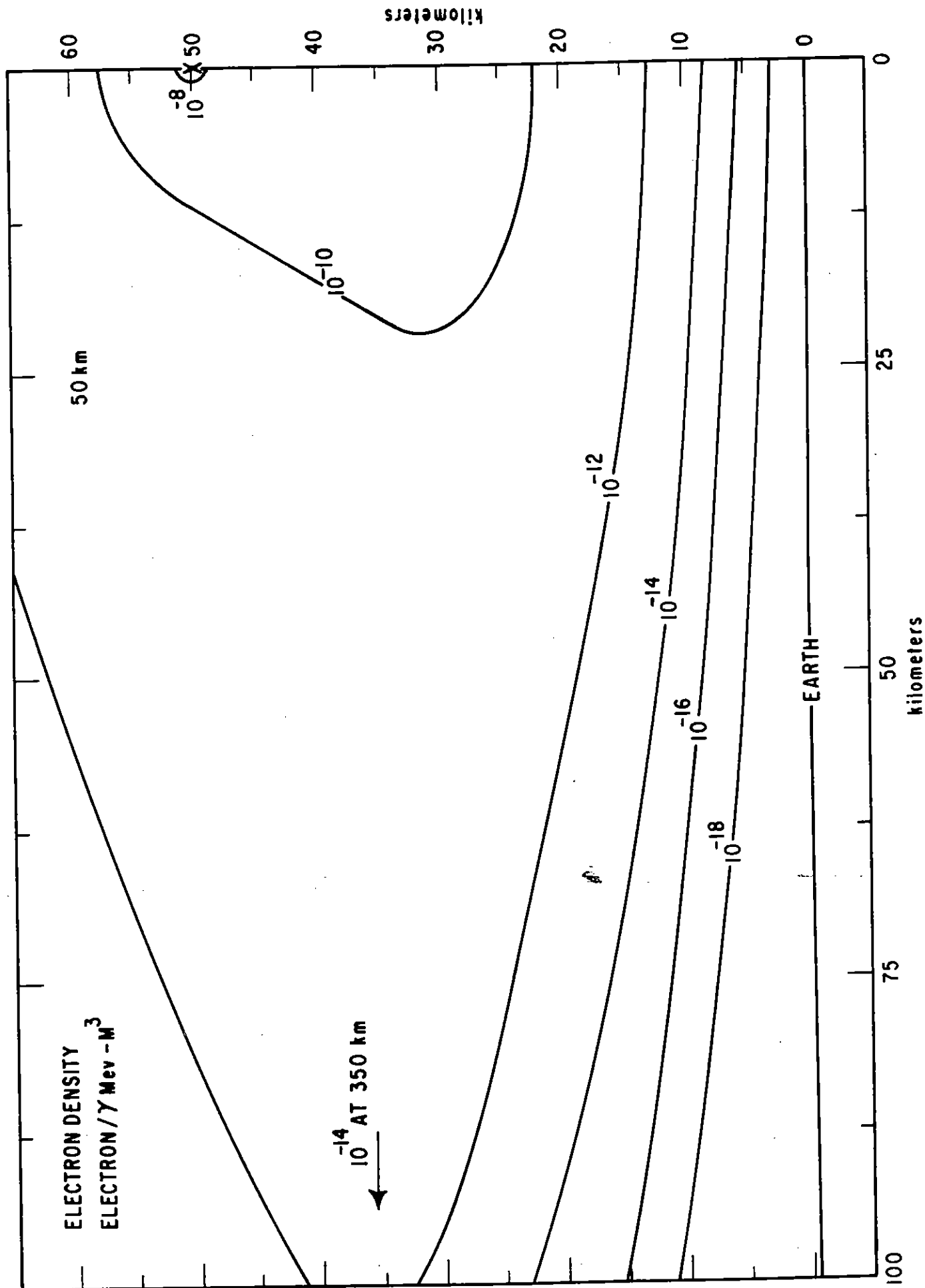


Fig. 7

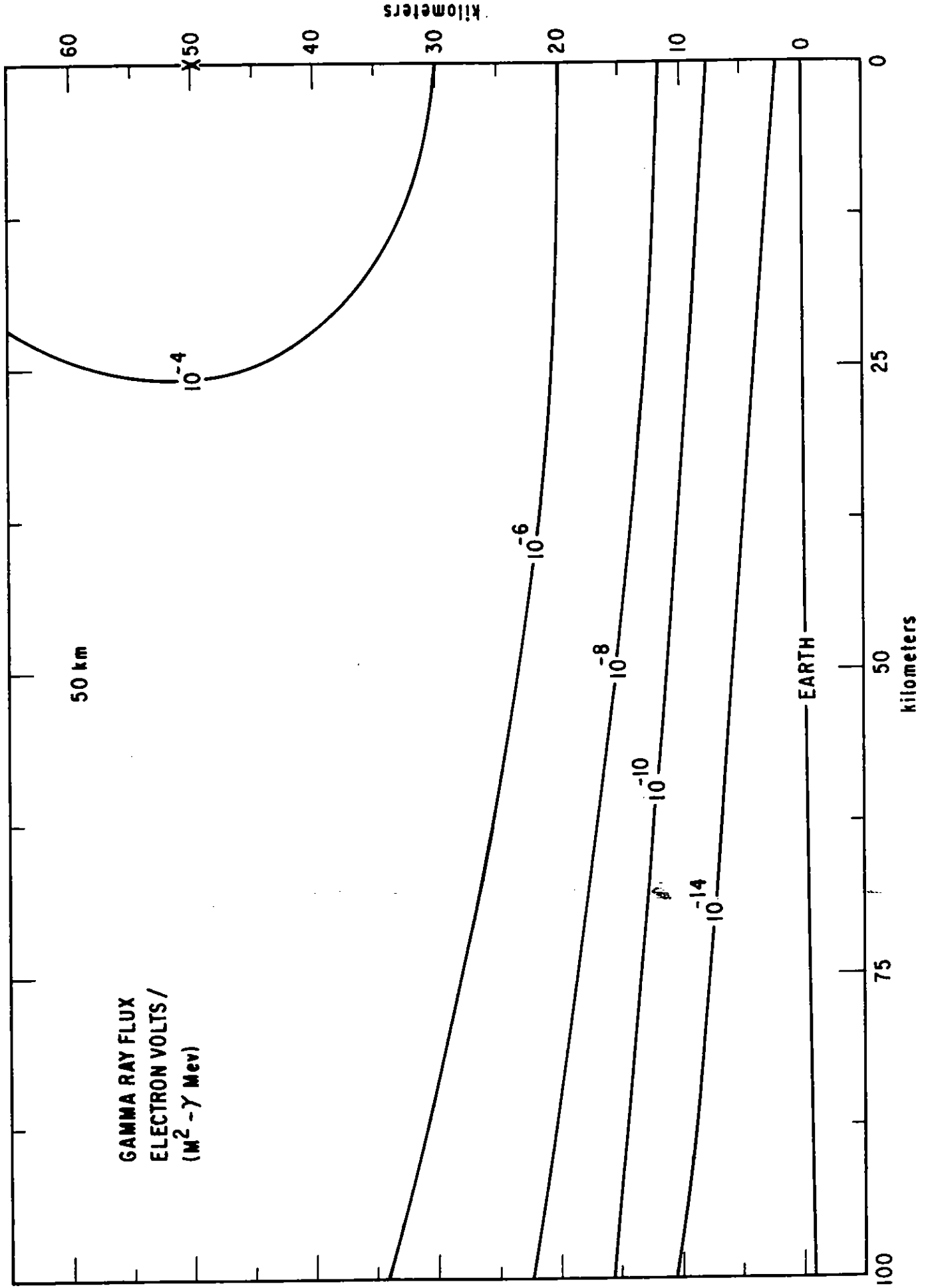


FIG. 8

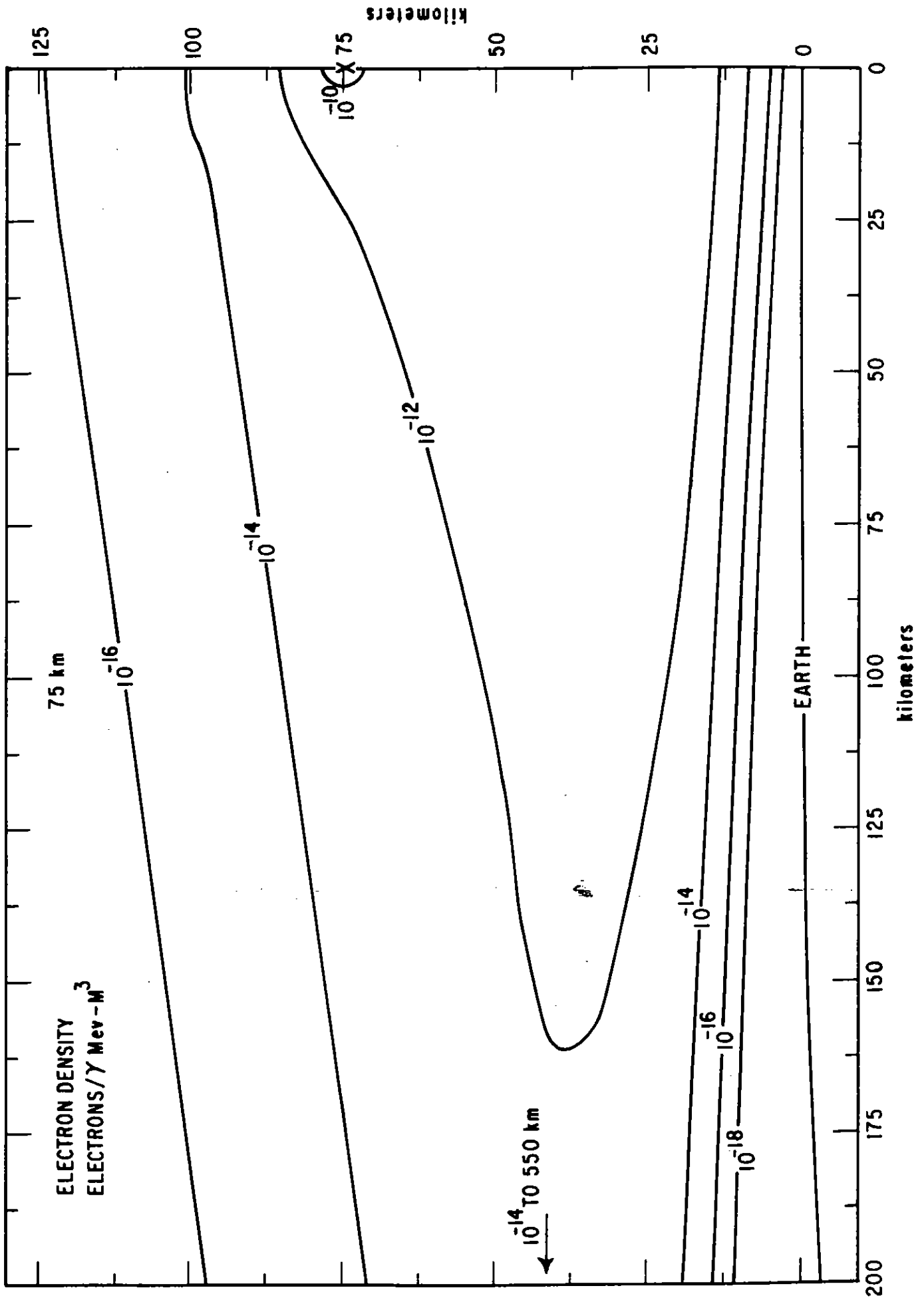


Fig. 9

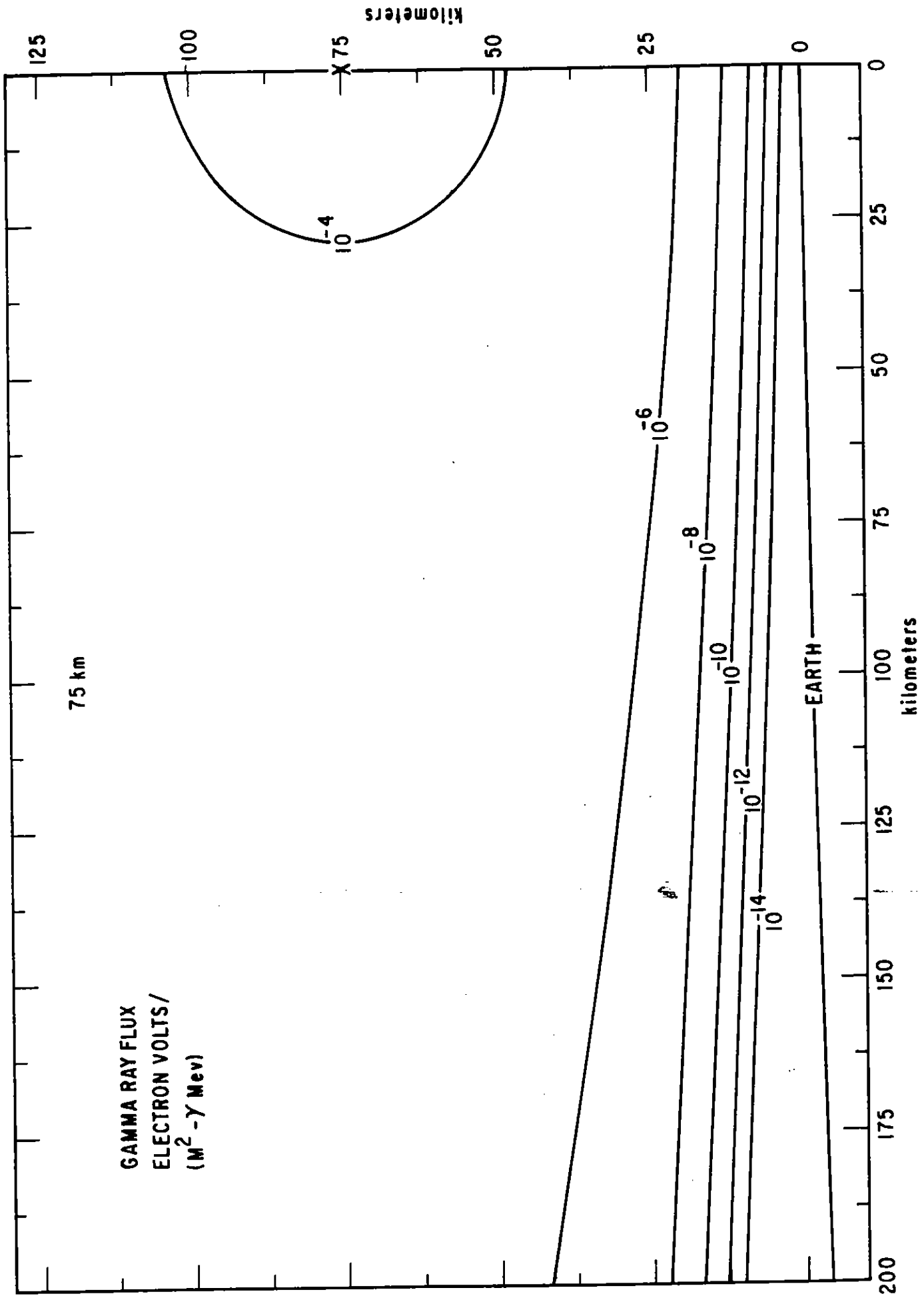


Fig. 10

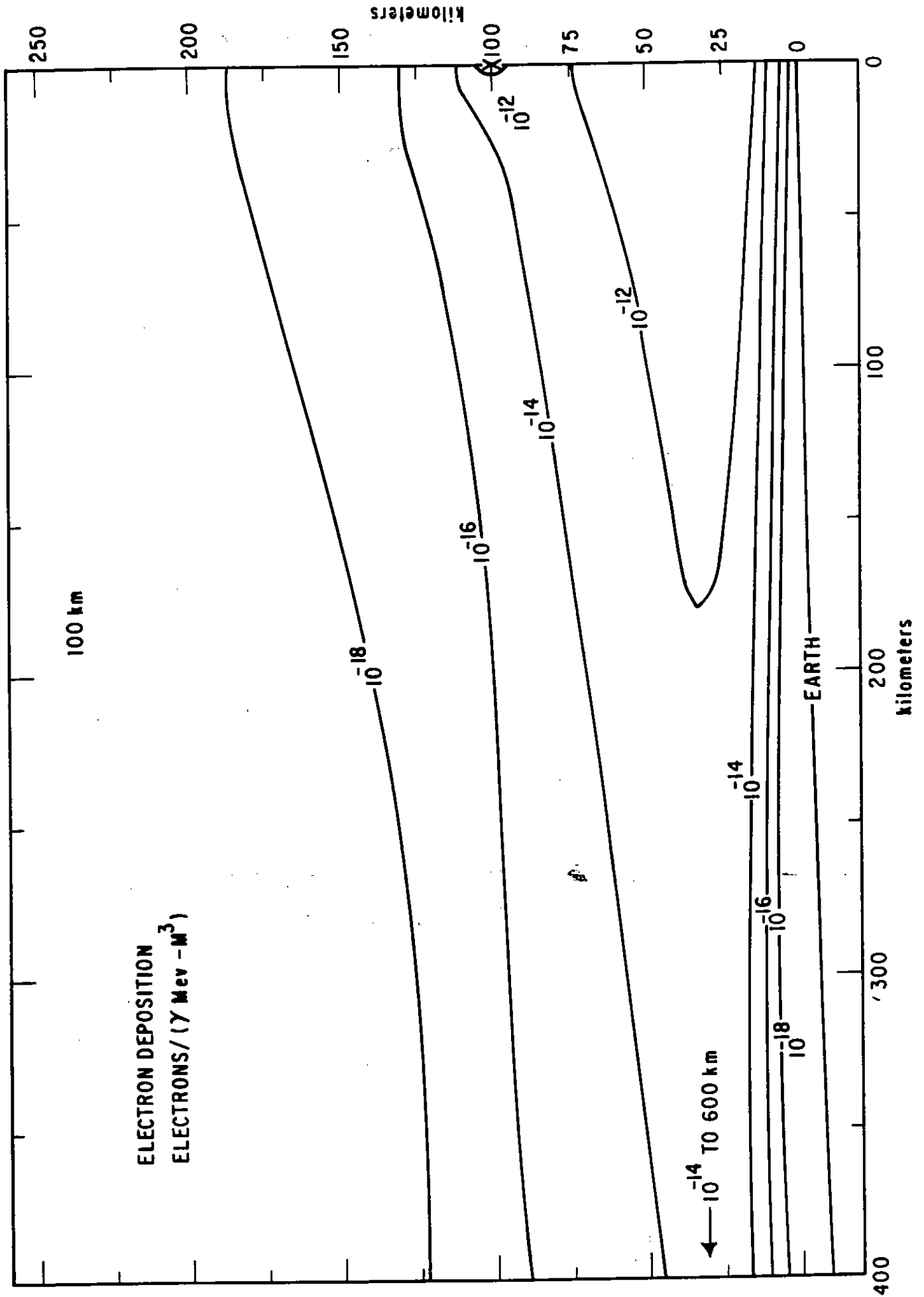


Fig. 11

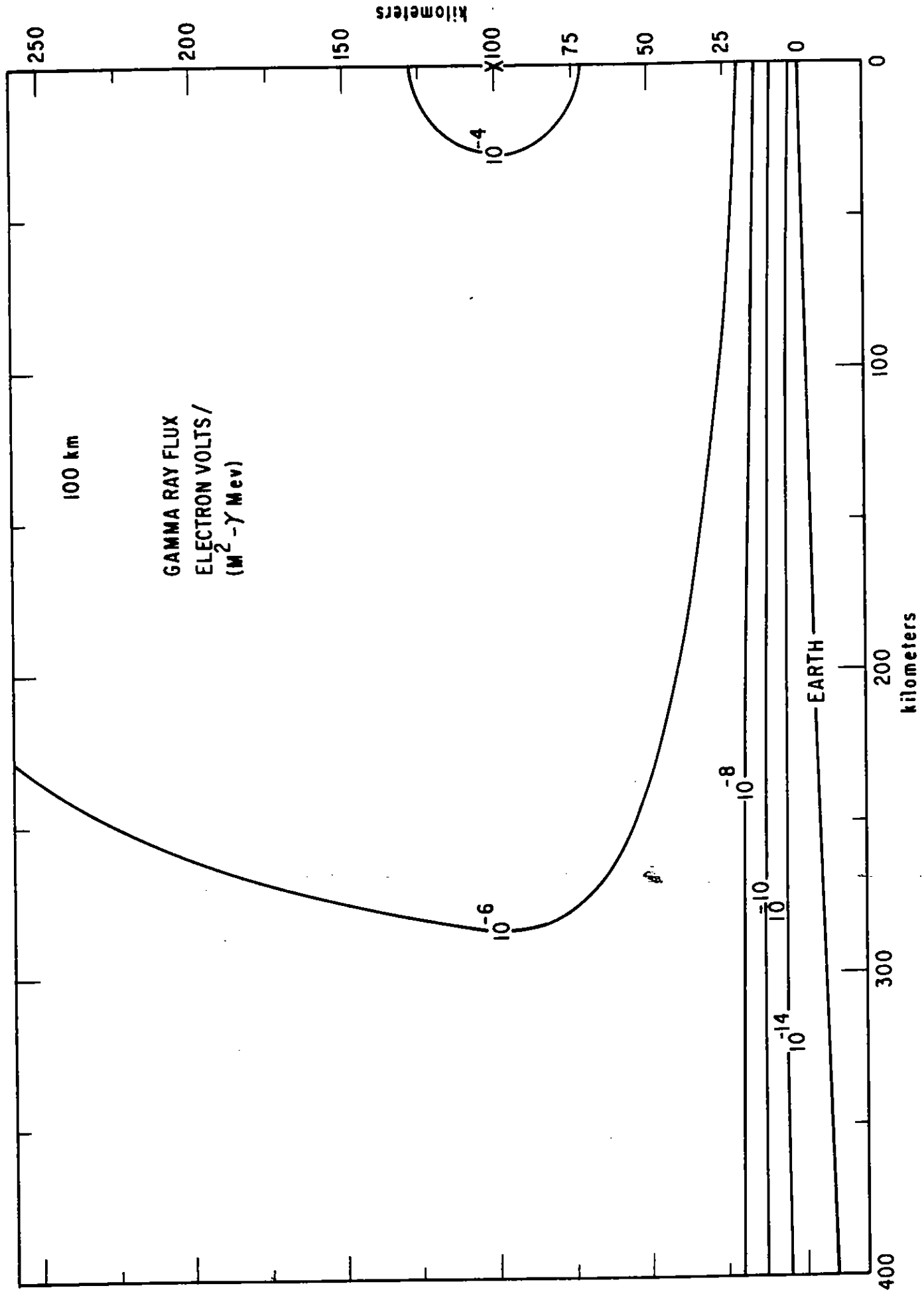


Fig. 12

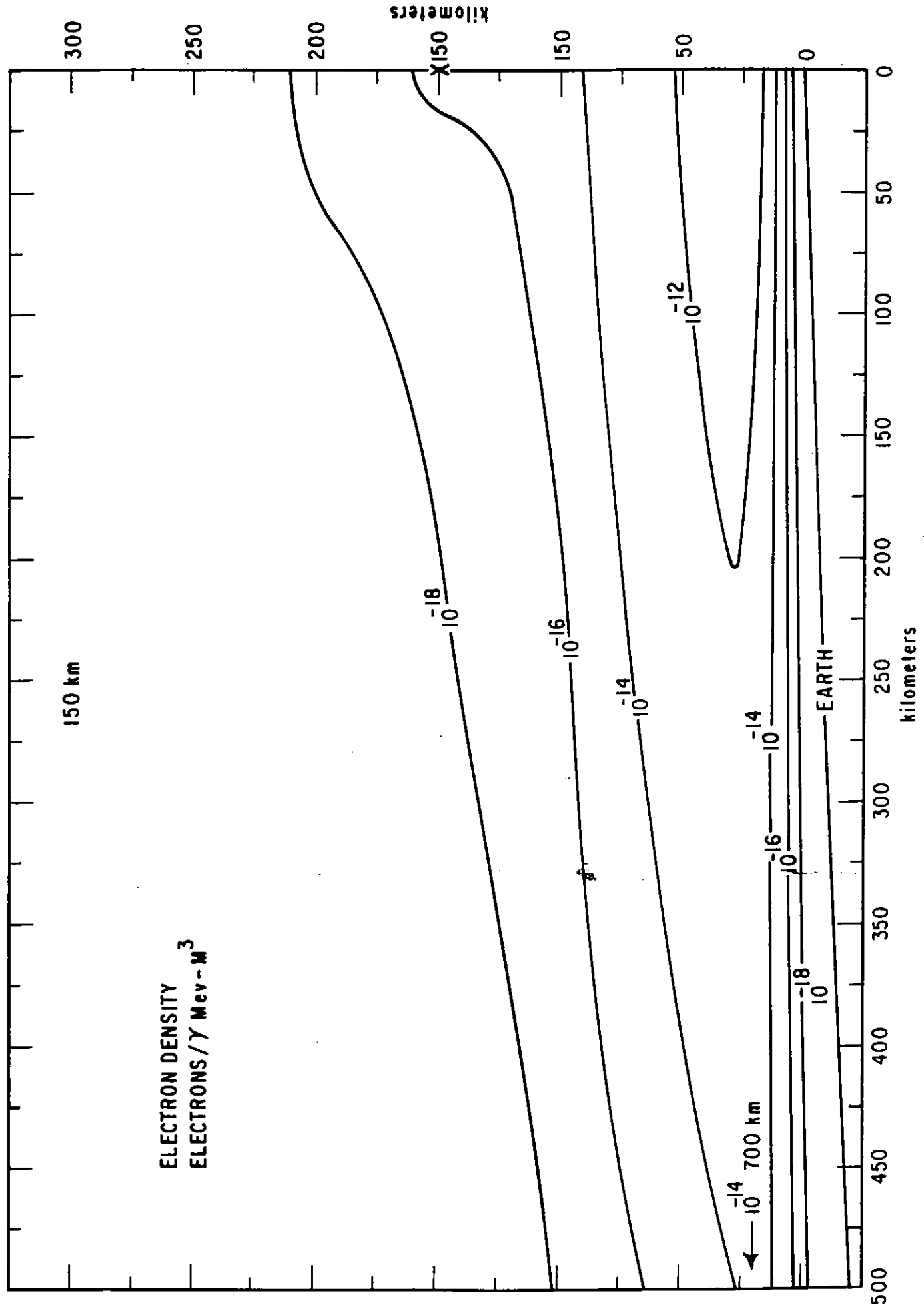


FIG. 13

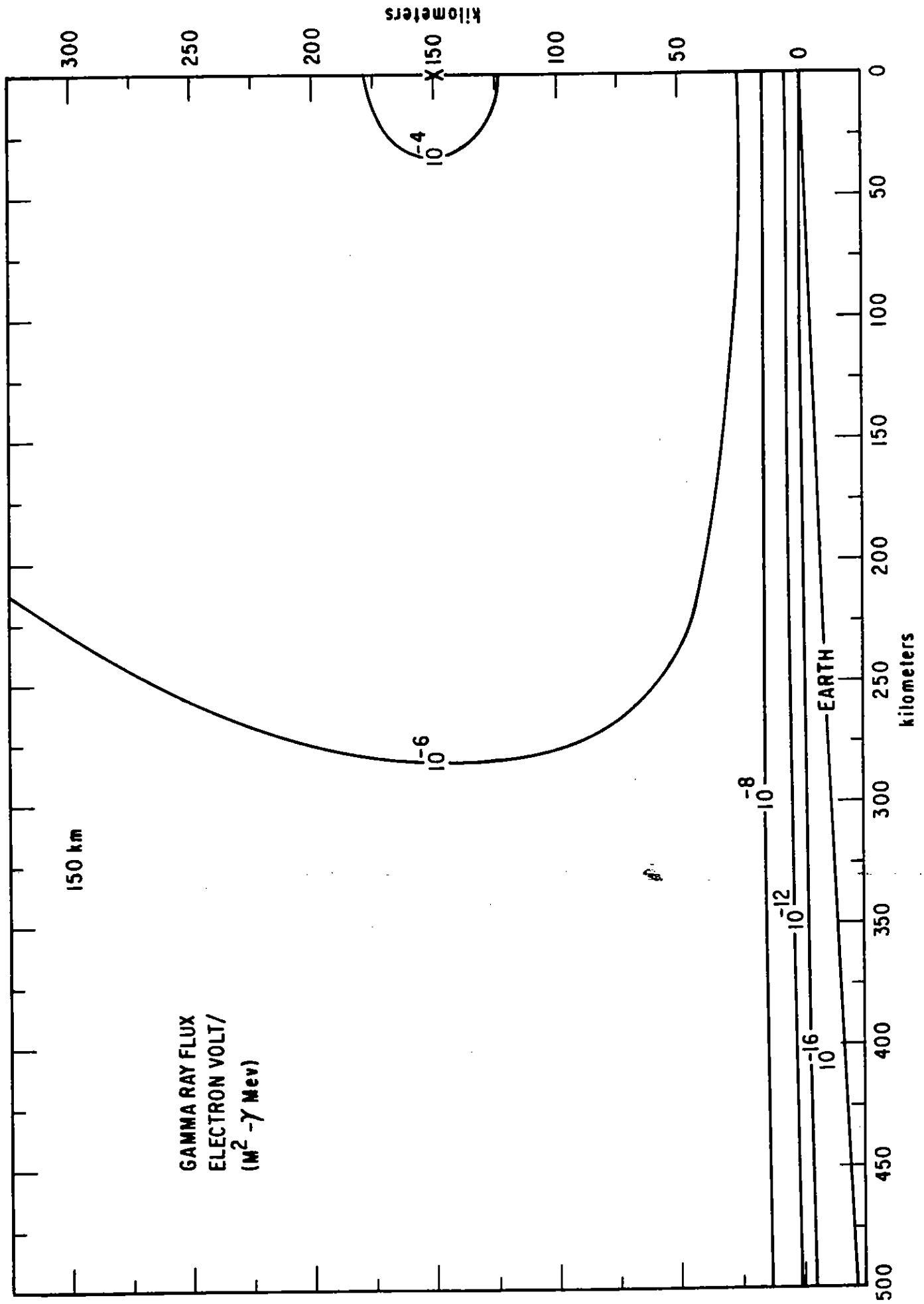


Fig. 14

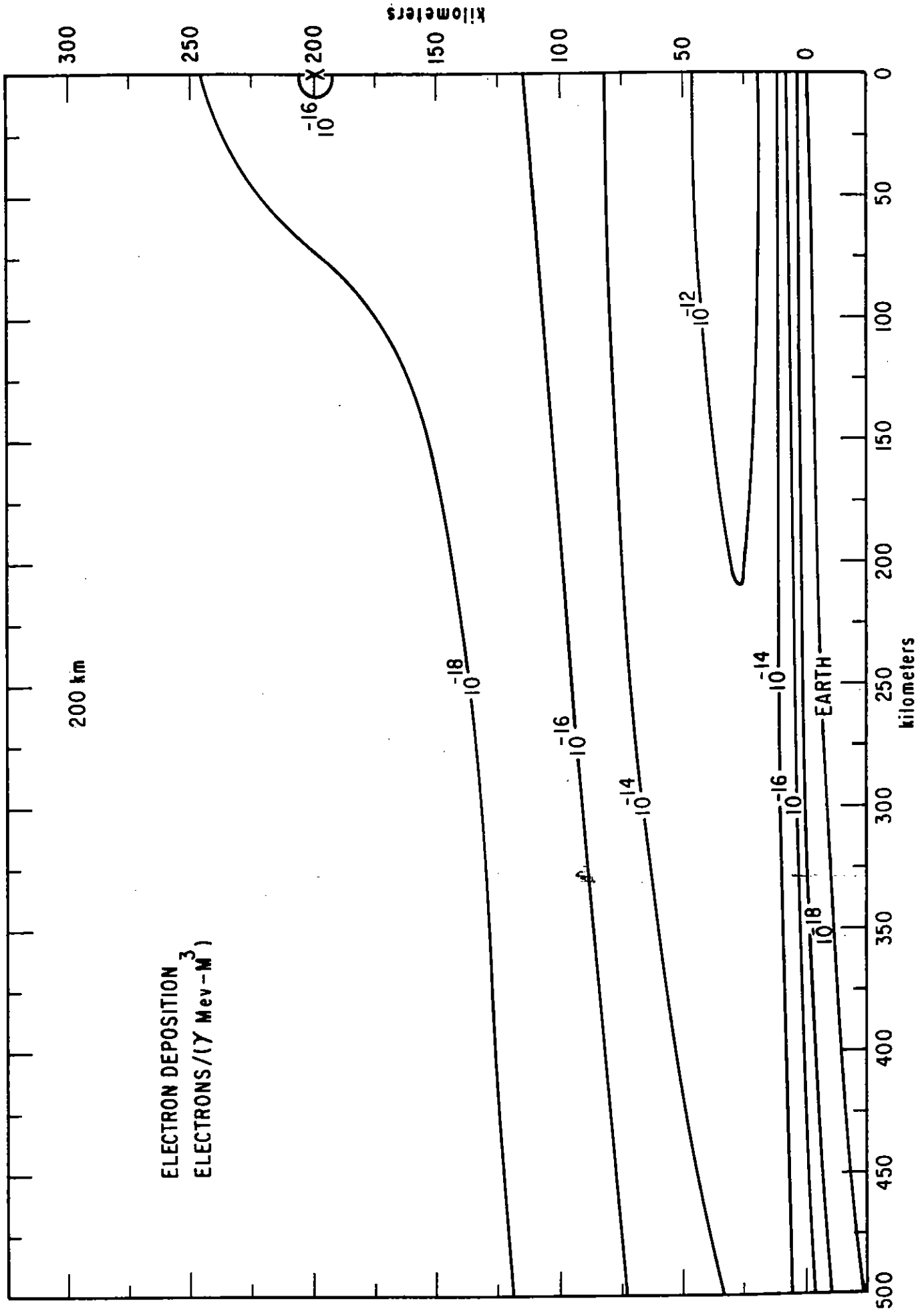


FIG. 15

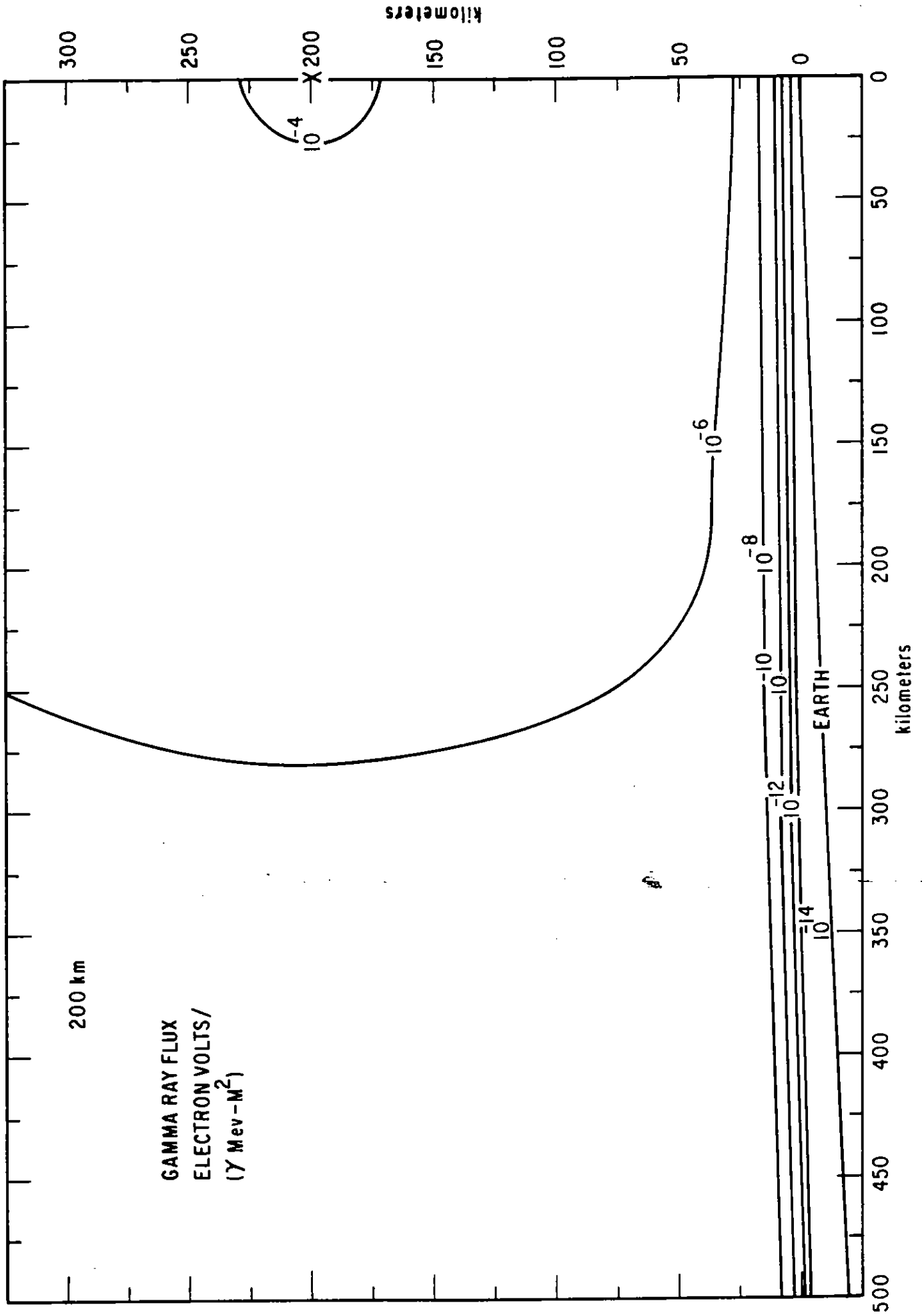


FIG. 16

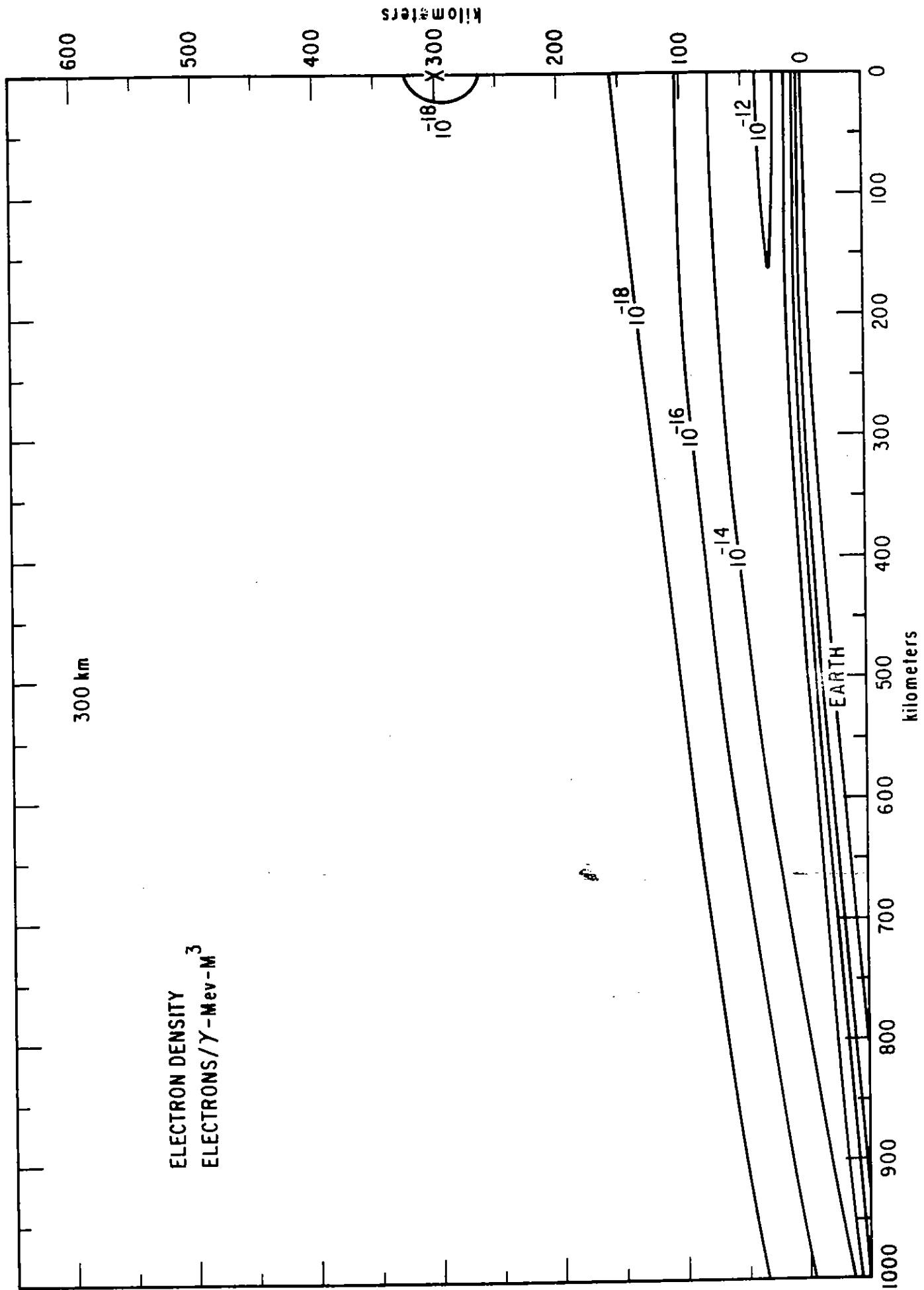


FIG. 17

