

Señores
DIVISIÓN DE NUEVAS CREACIONES
SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
Bogotá, D.C.

SUPERINDUSTRIA Y COMERCIO
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Trámite : 002 PATENTES D 1 REGISTRO/ 444 REPUESTA
Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

Re.: Código 02-01-444
Expediente No. 01-43.631
Solicitud de Patente
SCHLUMBERGER HOLDINGS
LIMITED

En relación con el expediente de la referencia y dando cumplimiento a la última providencia recaída sobre este asunto por medio del presente escrito me permito manifestarles lo siguiente:

1. Acompaño un nuevo juego de figuras, debidamente corregidas. /
2. Adjunto el arte final por triplicado. /
3. También acompaño la copia certificada de la solicitud básica de patente de la cual se reclama prioridad. /
4. Finalmente, se adjunta el documento mediante el cual se acredita la cesión del inventor a la sociedad solicitante.

Renuncio al término faltante de traslado, y les solicito ordenar la publicación del extracto.

De Ustedes Atentamente,

GERMAN CASTILLO GRAU
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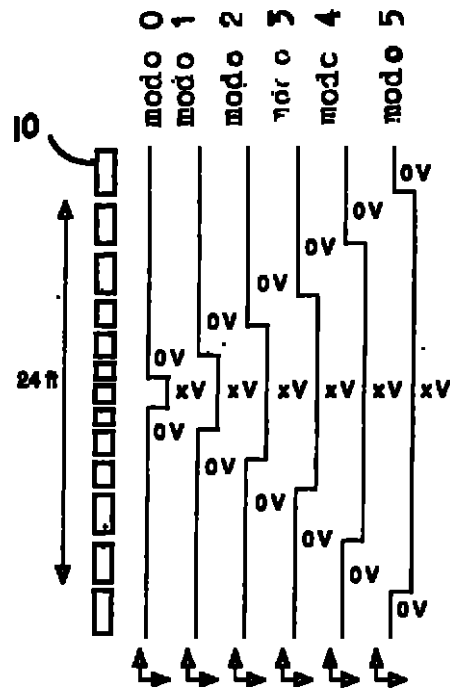


FIG. 1

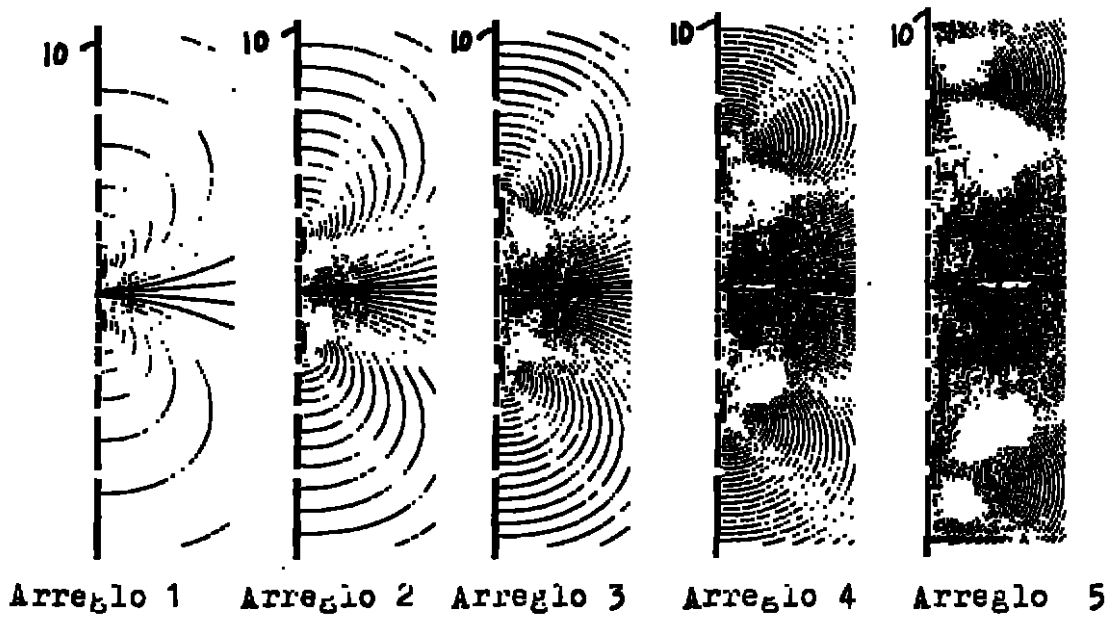


FIG. 2

✓

Formación anisotrópica
no invadida

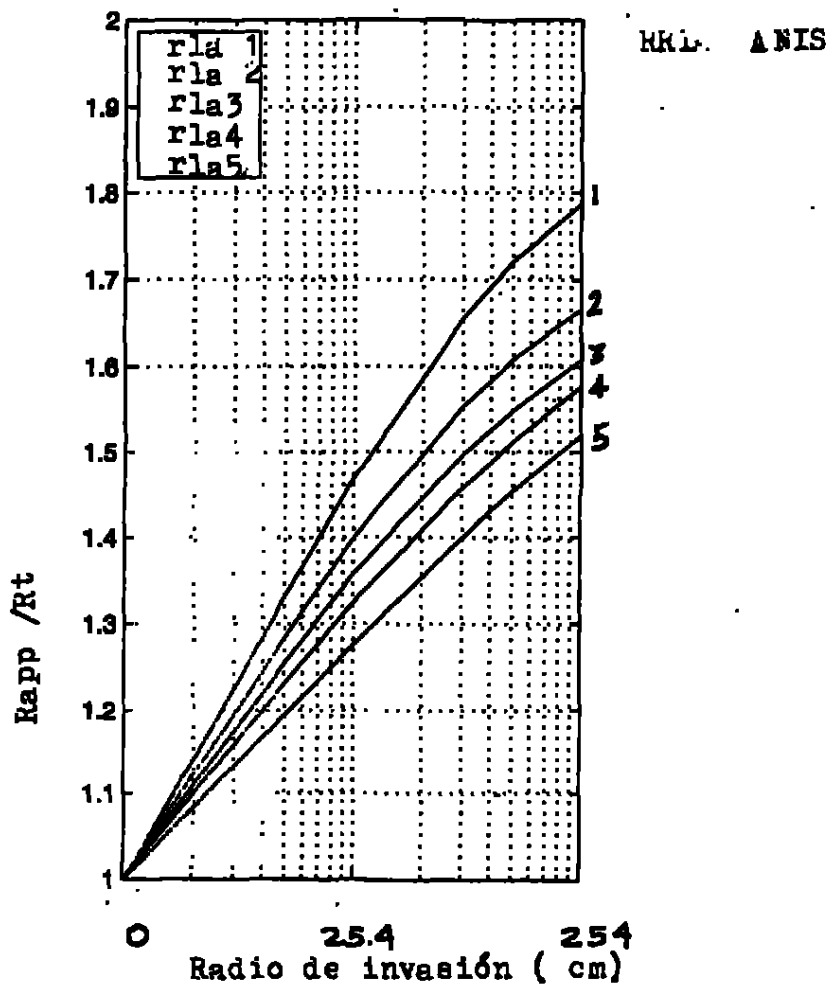


FIG. 3

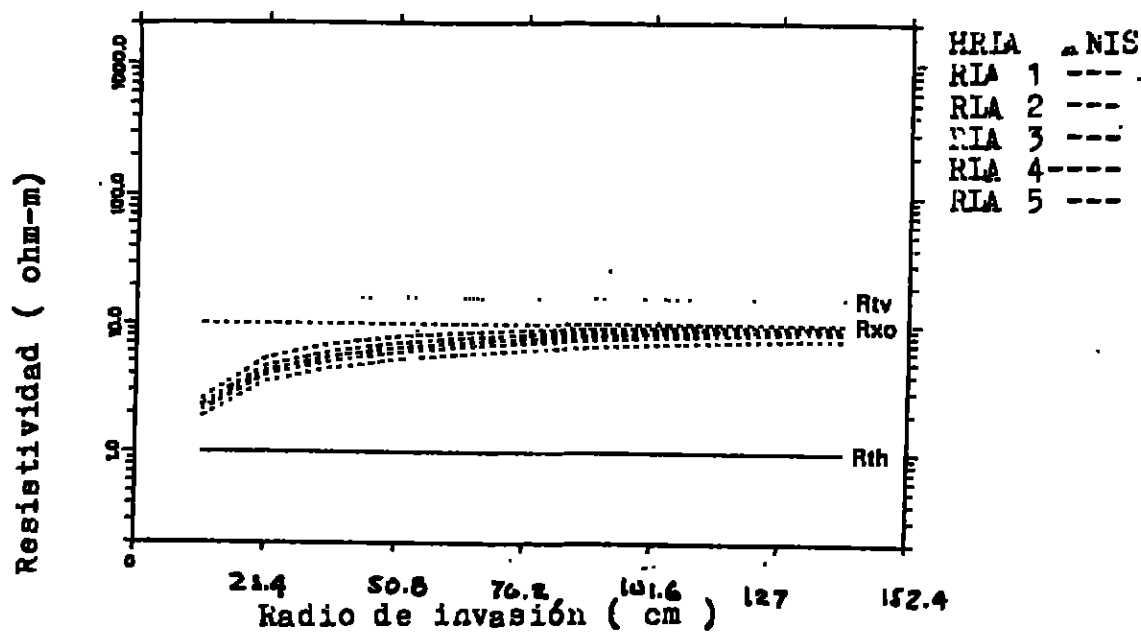


FIG. 4

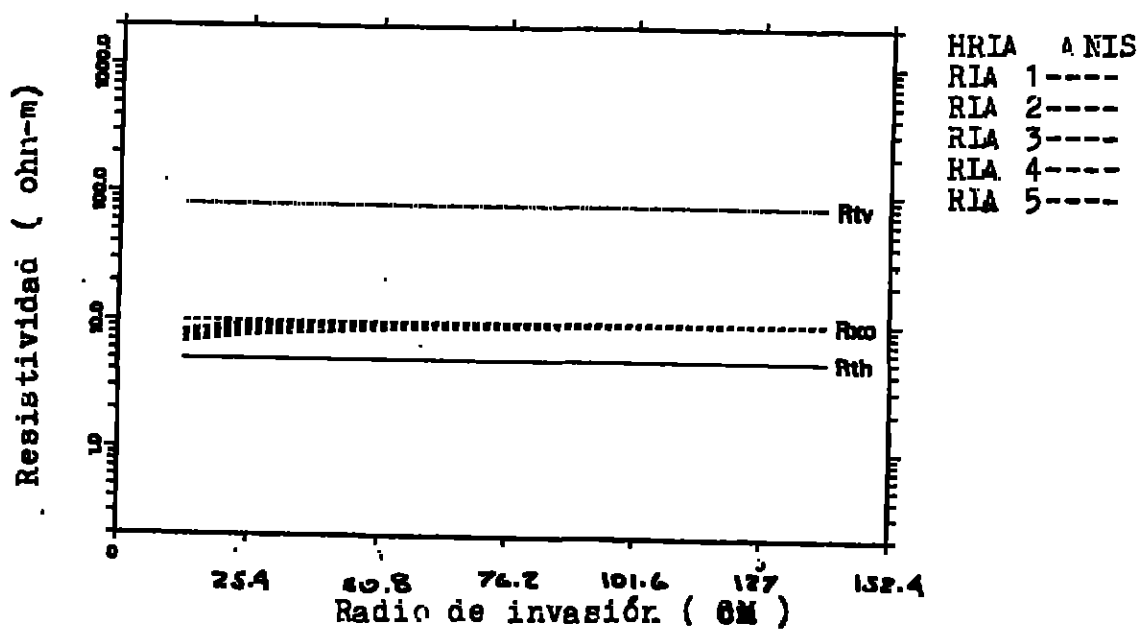


FIG. 5

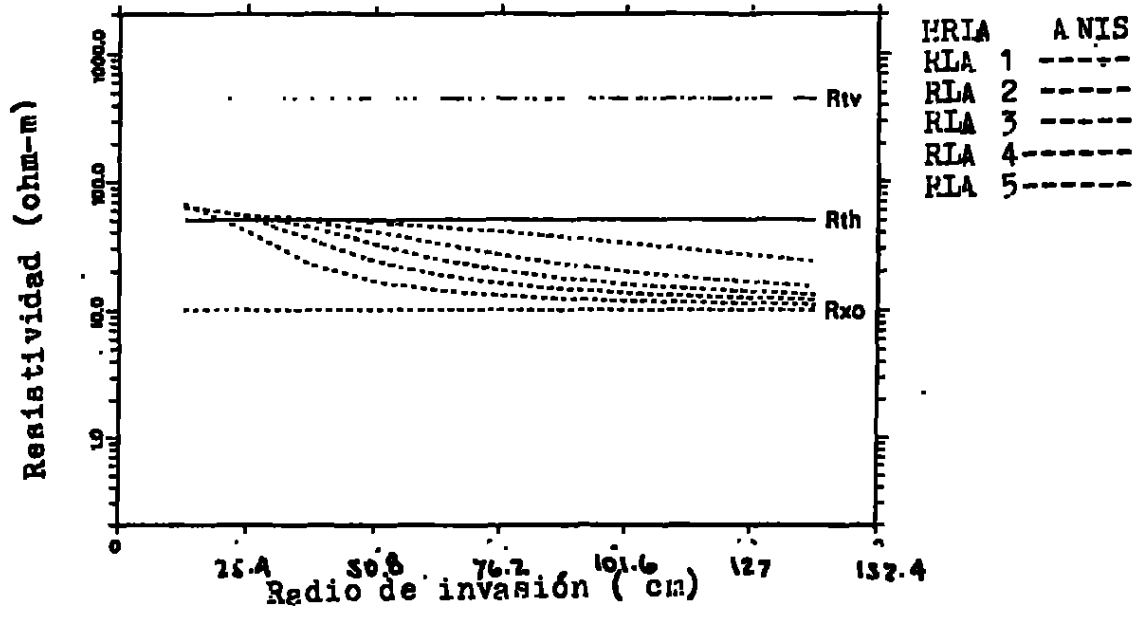


FIG. 6

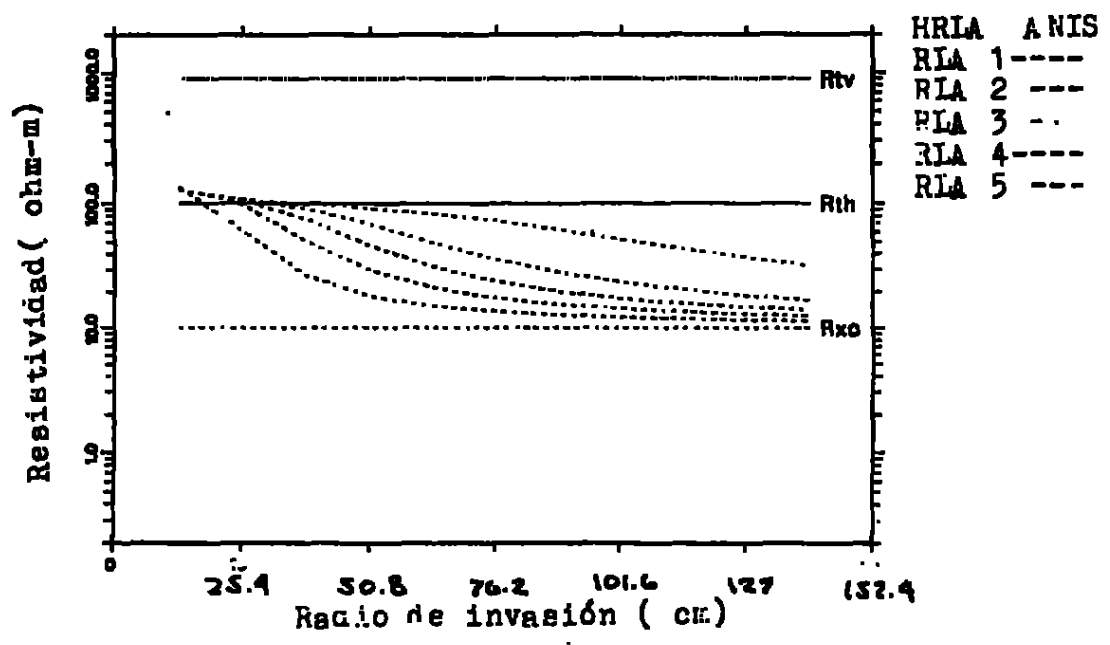


FIG. 7

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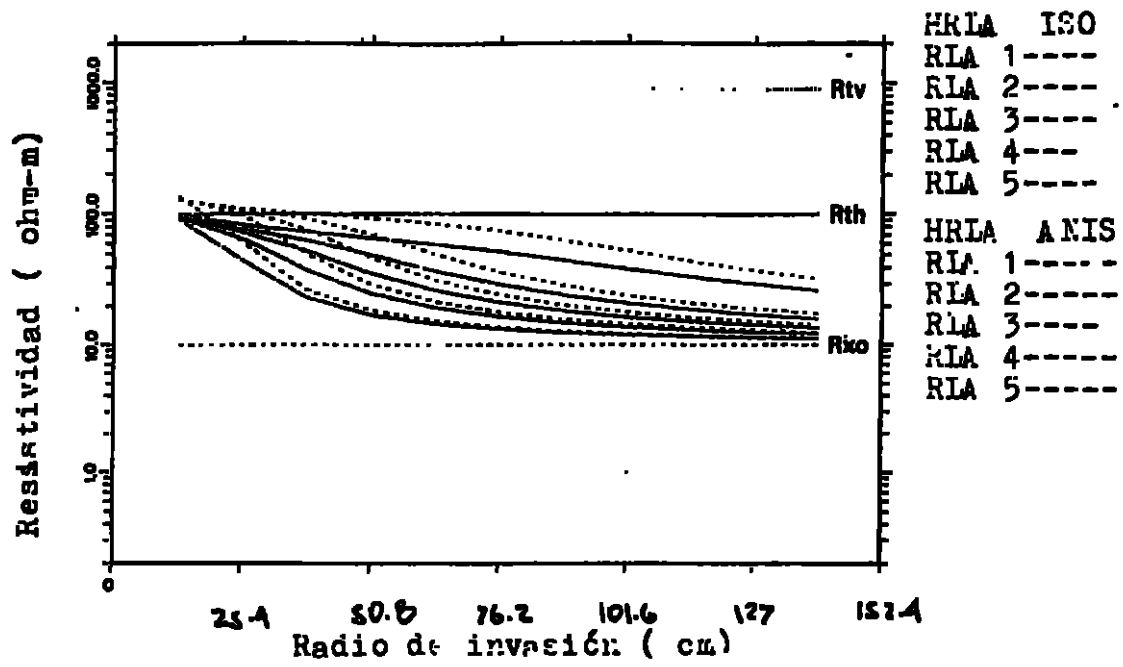


FIG. 8

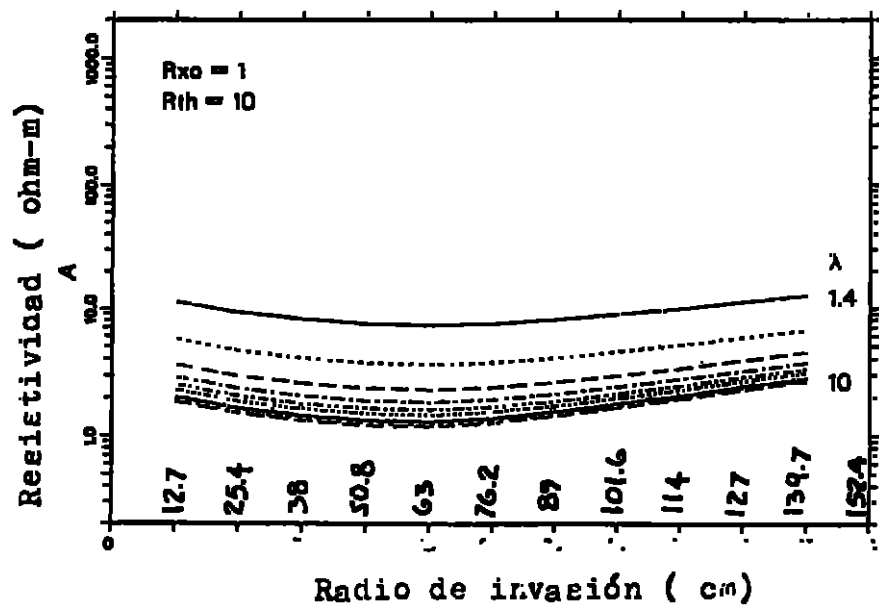


FIG. 9

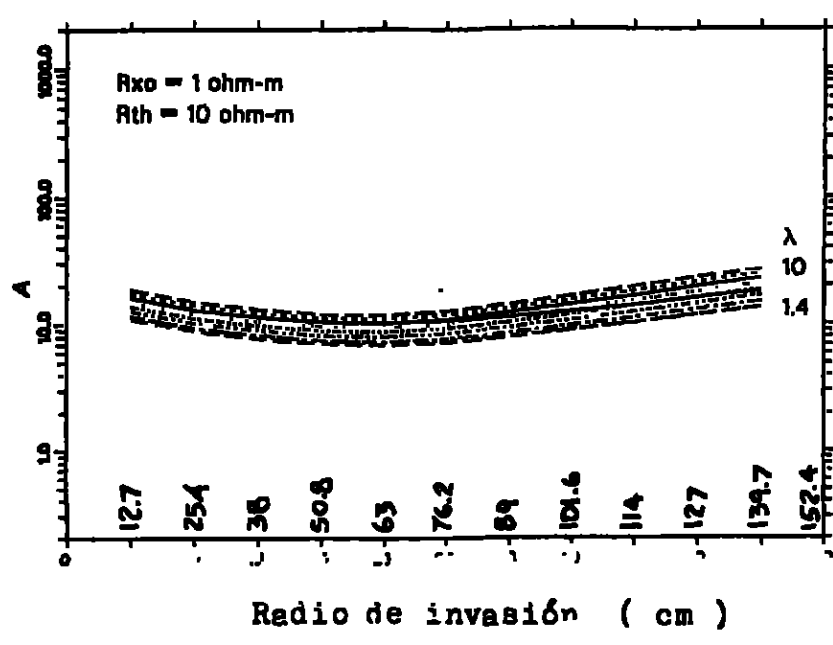


FIG. 10

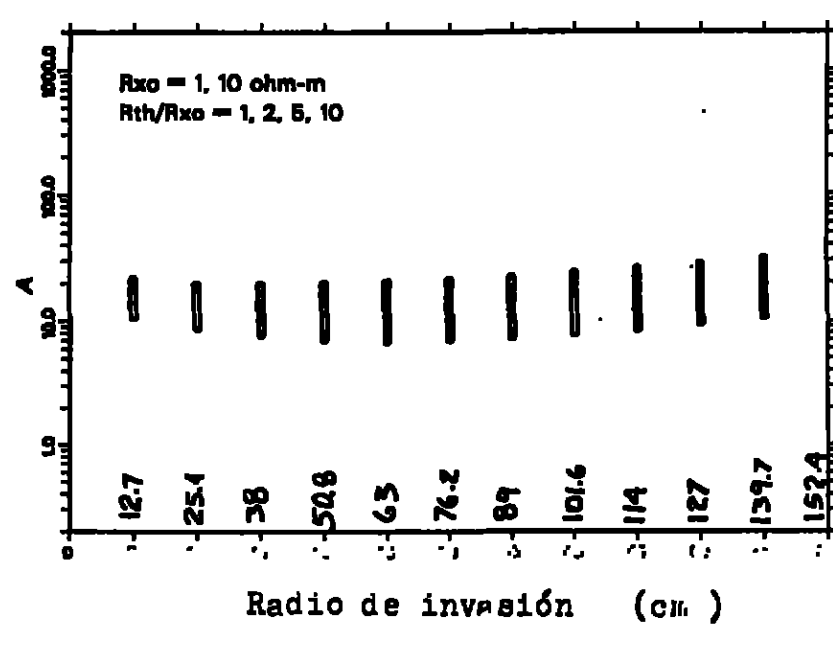
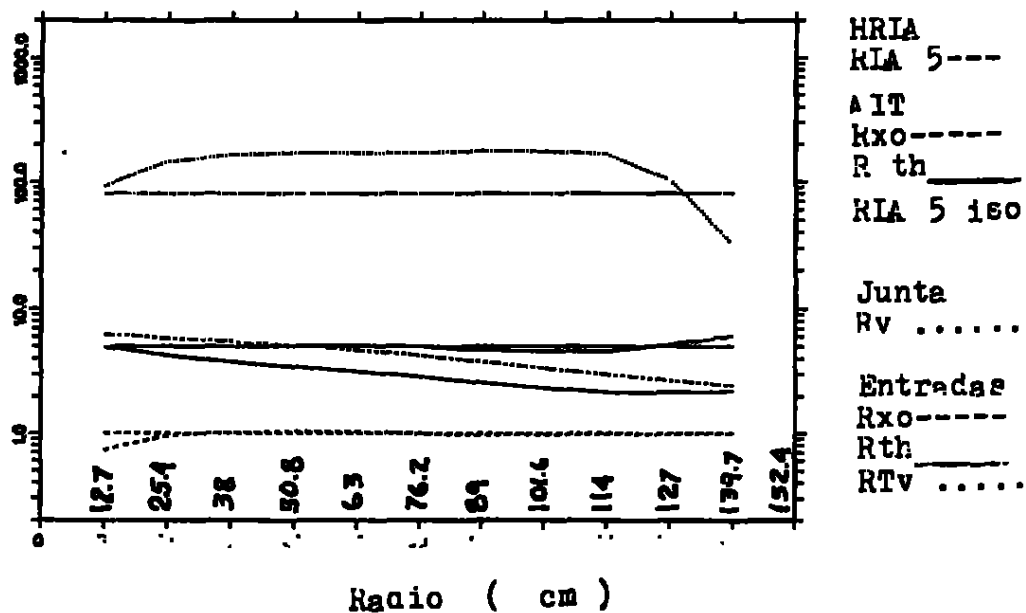
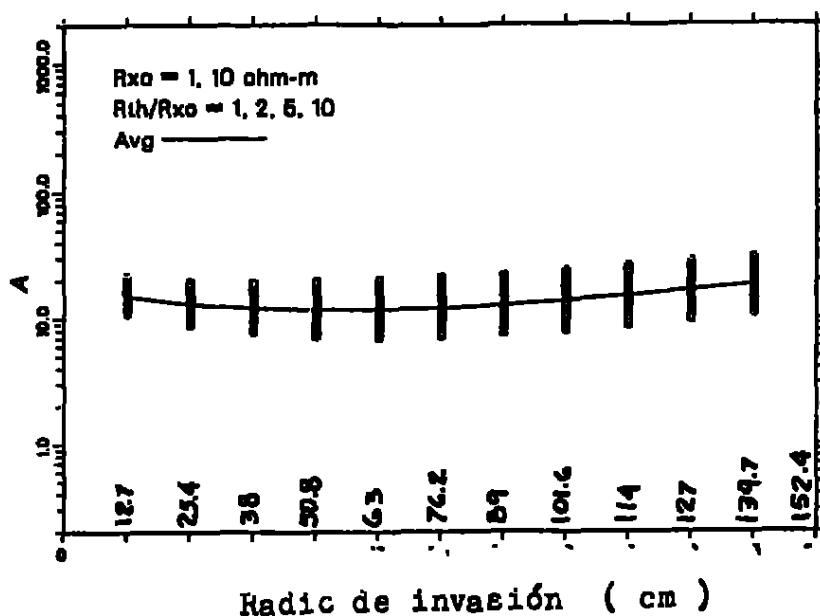


FIG. 11



SA 50

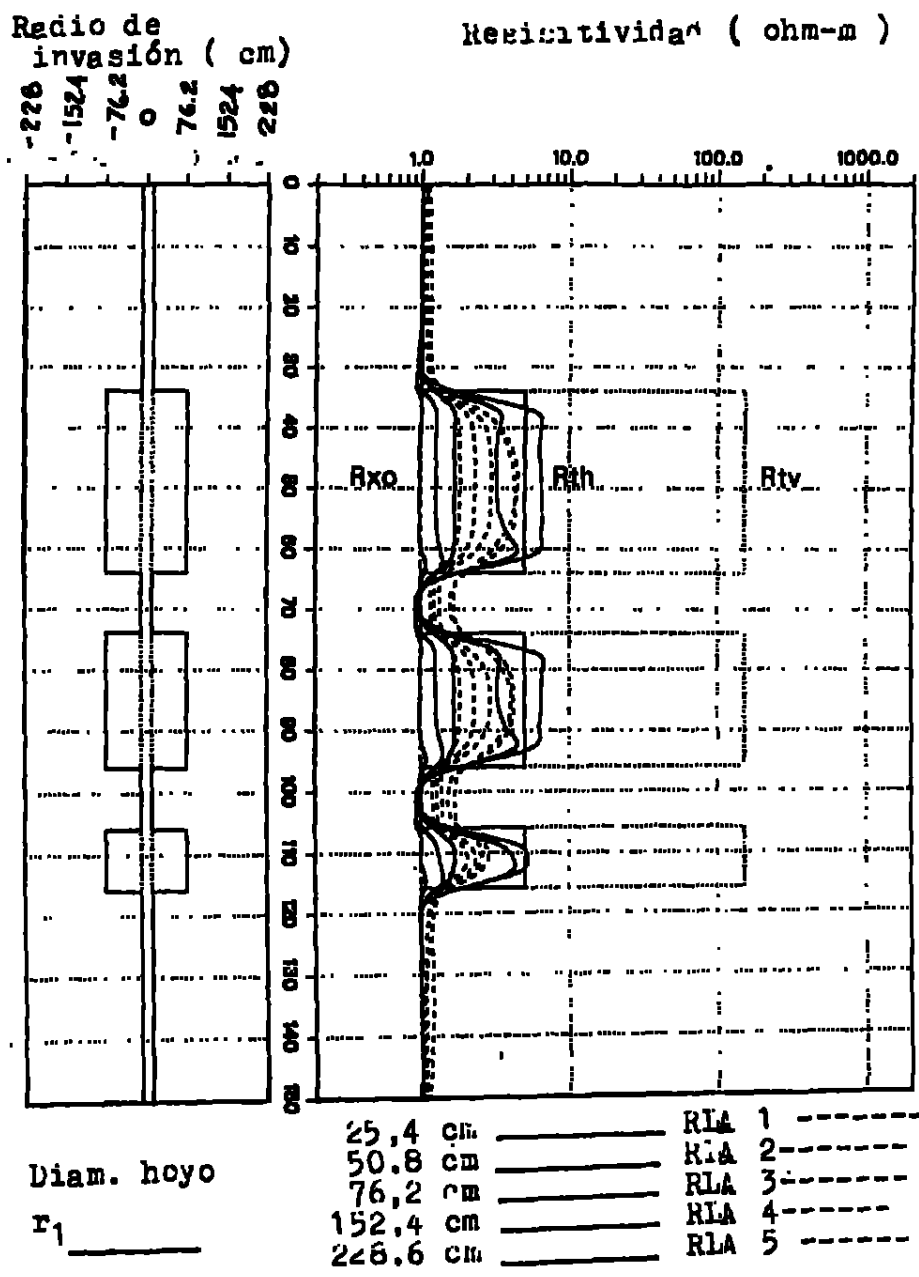


FIG. 14

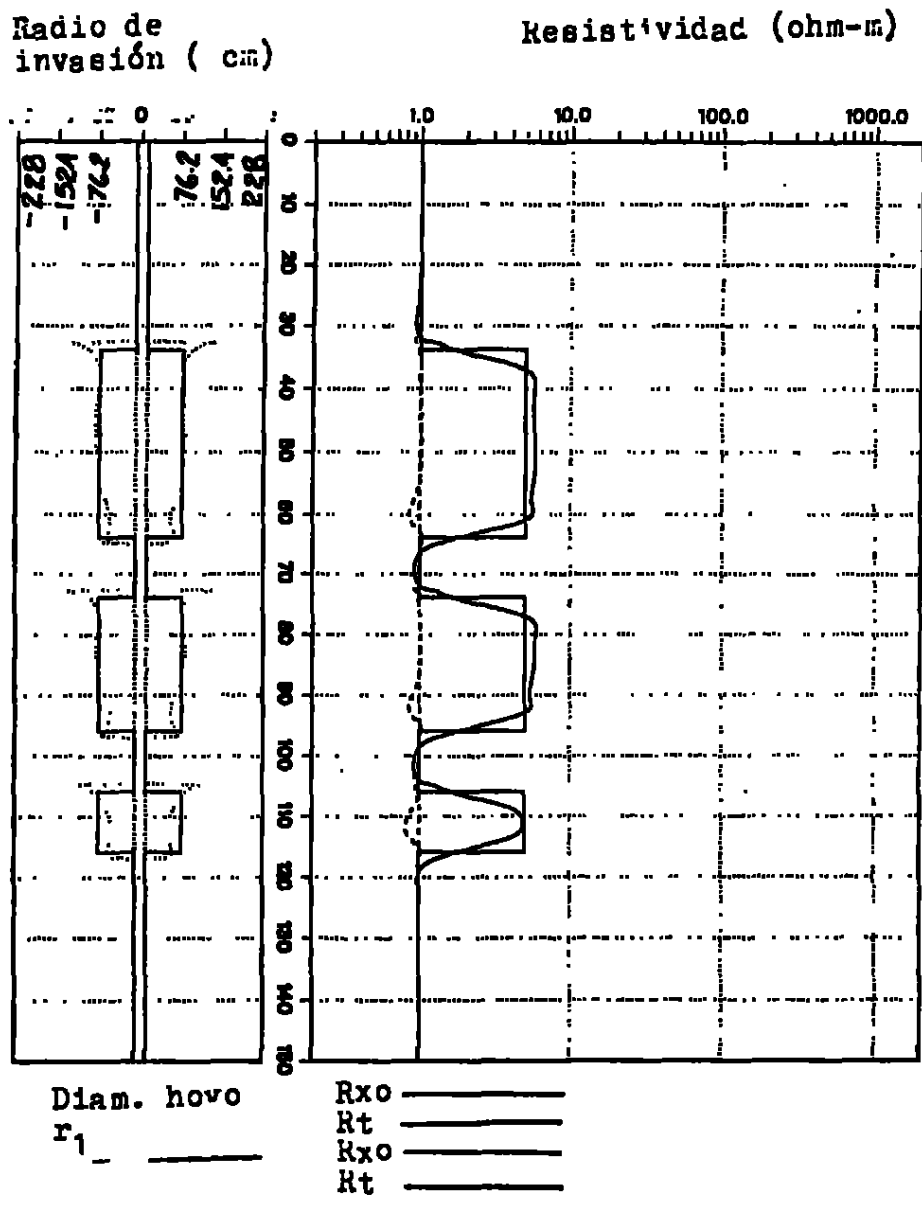


FIG. 15

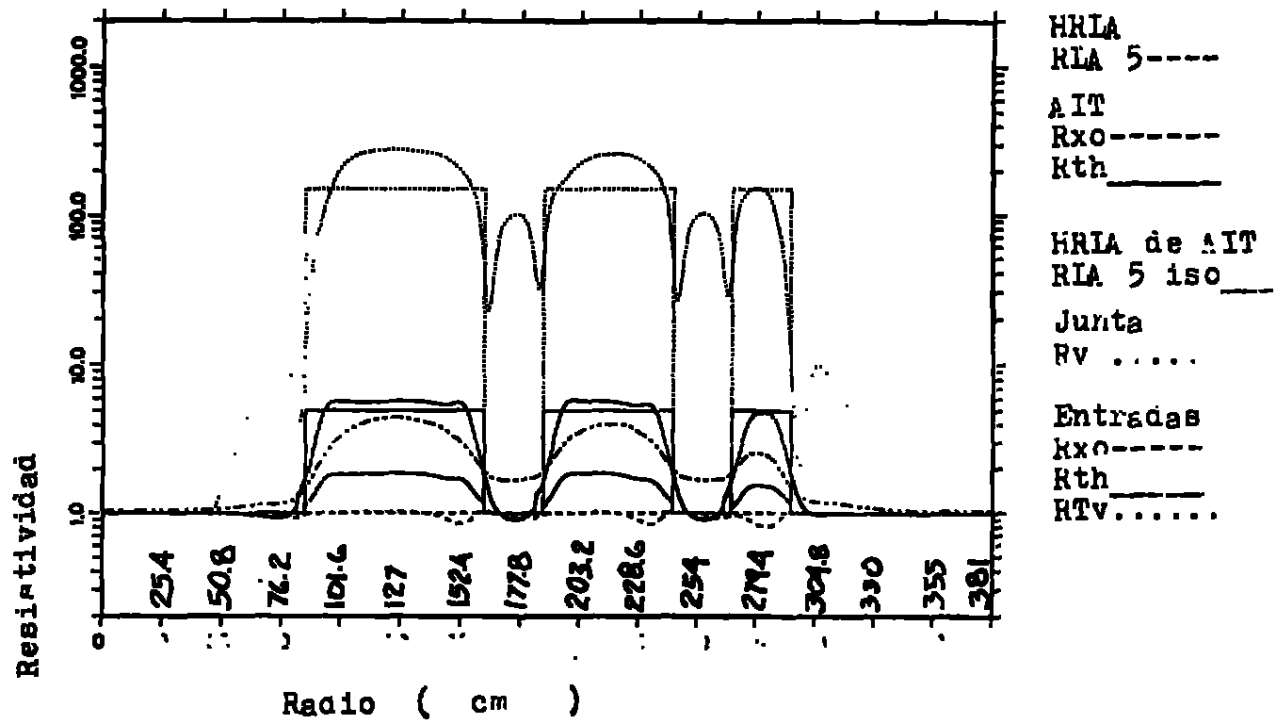
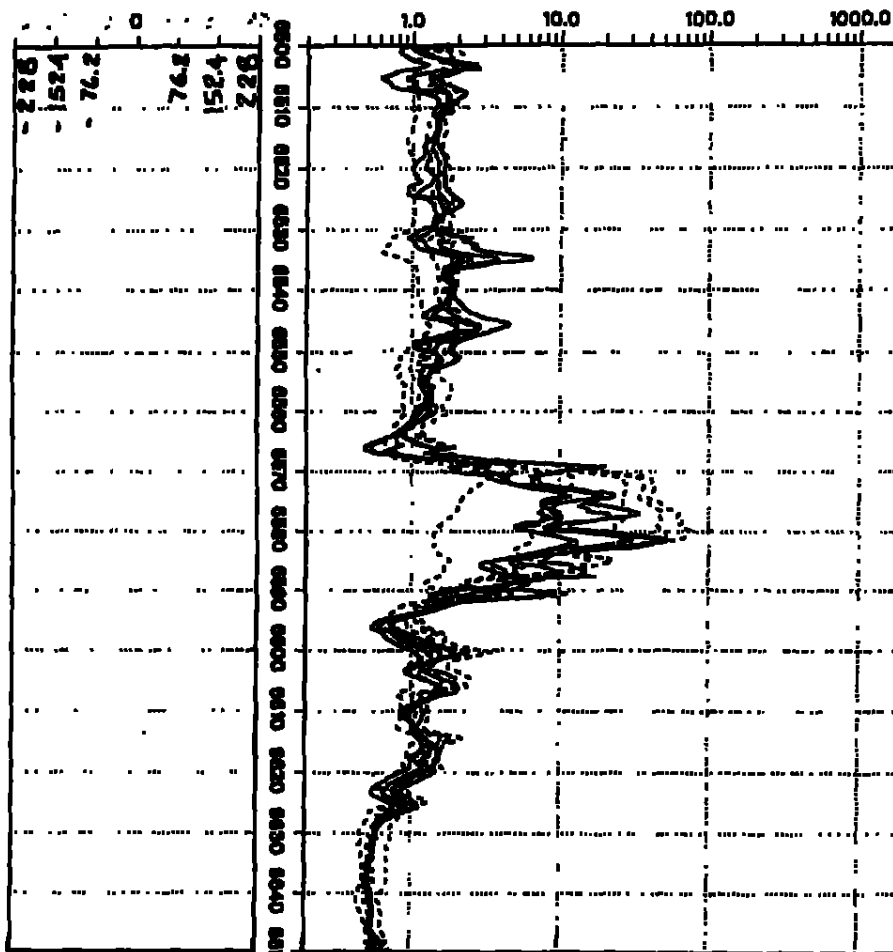


FIG. 16

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Radio de
invasión (cm)

Resistividad (ohm- m)



Diam. hoyo....

- 25,4 cm — RIA 1
- 50,8 cm — RIA 2
- 76,2 cm — RIA 3
- 152,4 cm — RIA 4
- 228,6 cm — RIA 5

FIG. 17

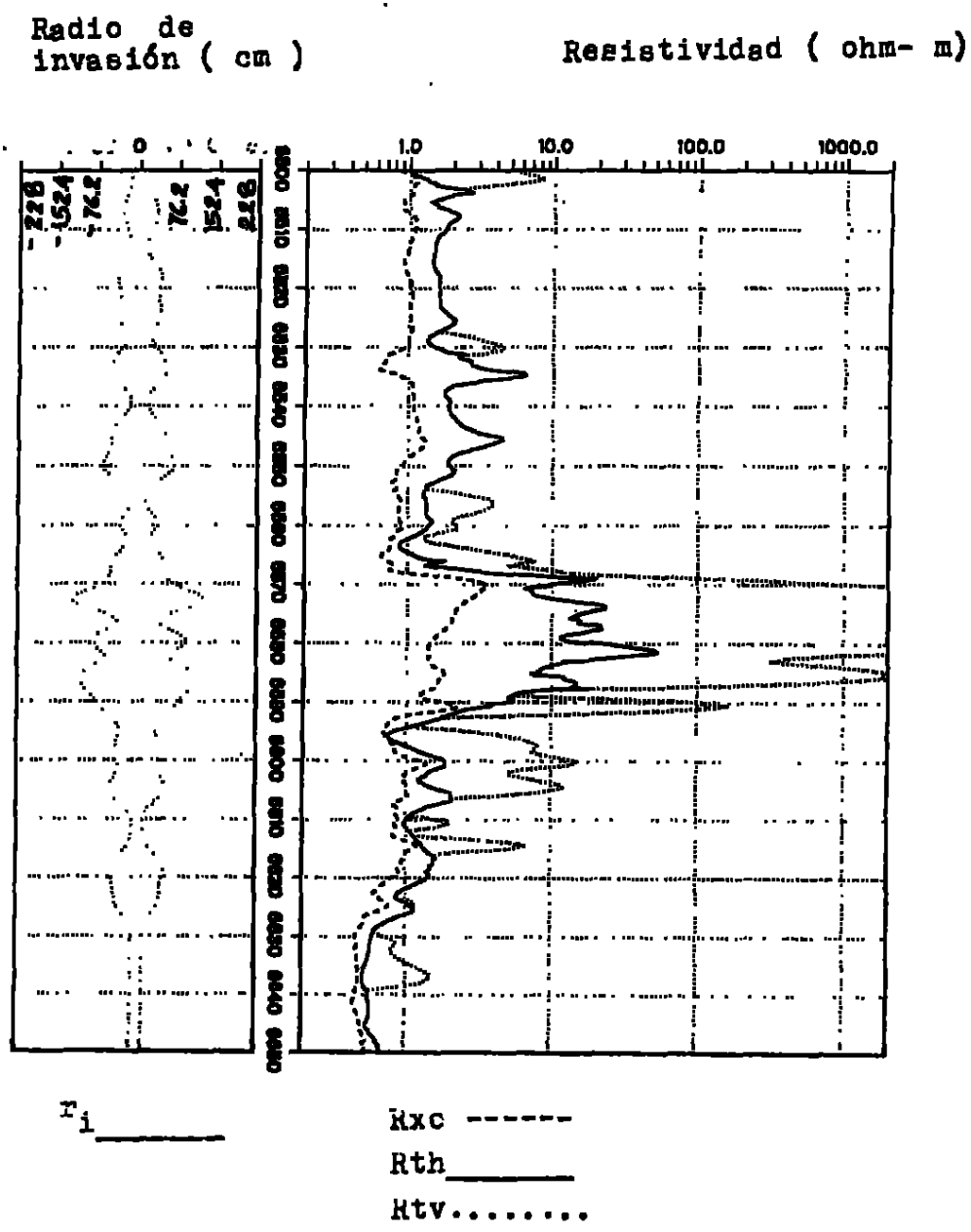
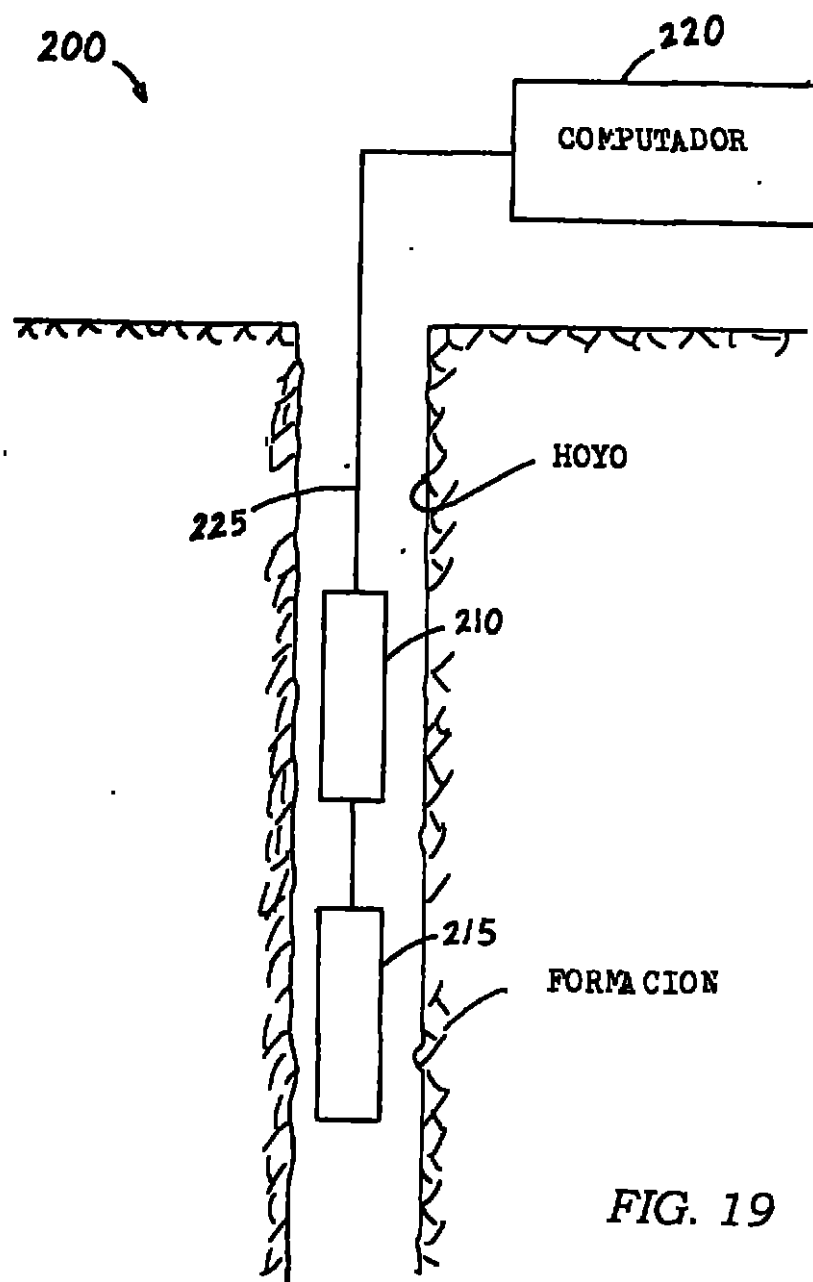


FIG. 18



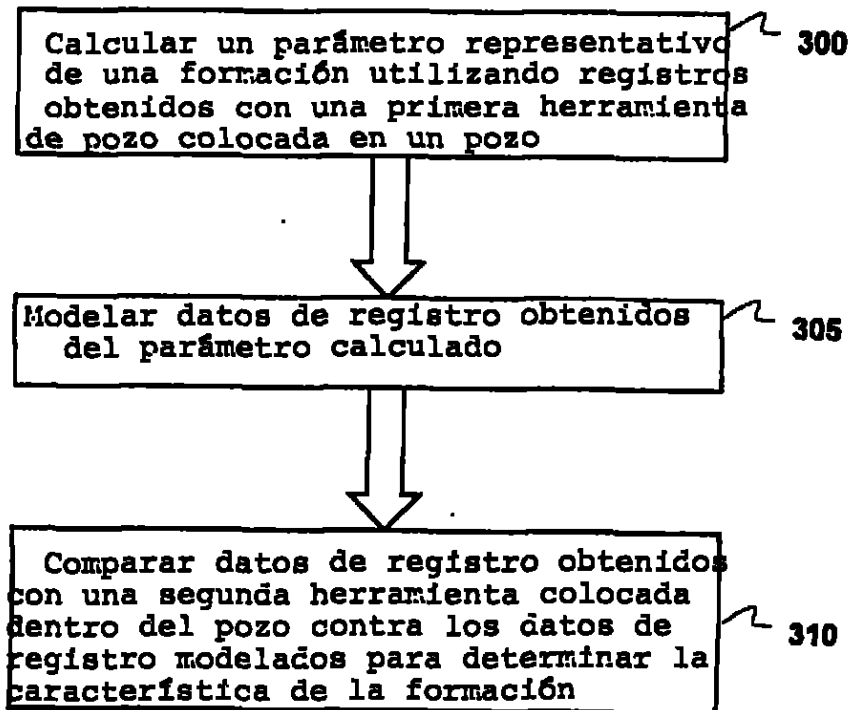


FIG. 20

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64.57

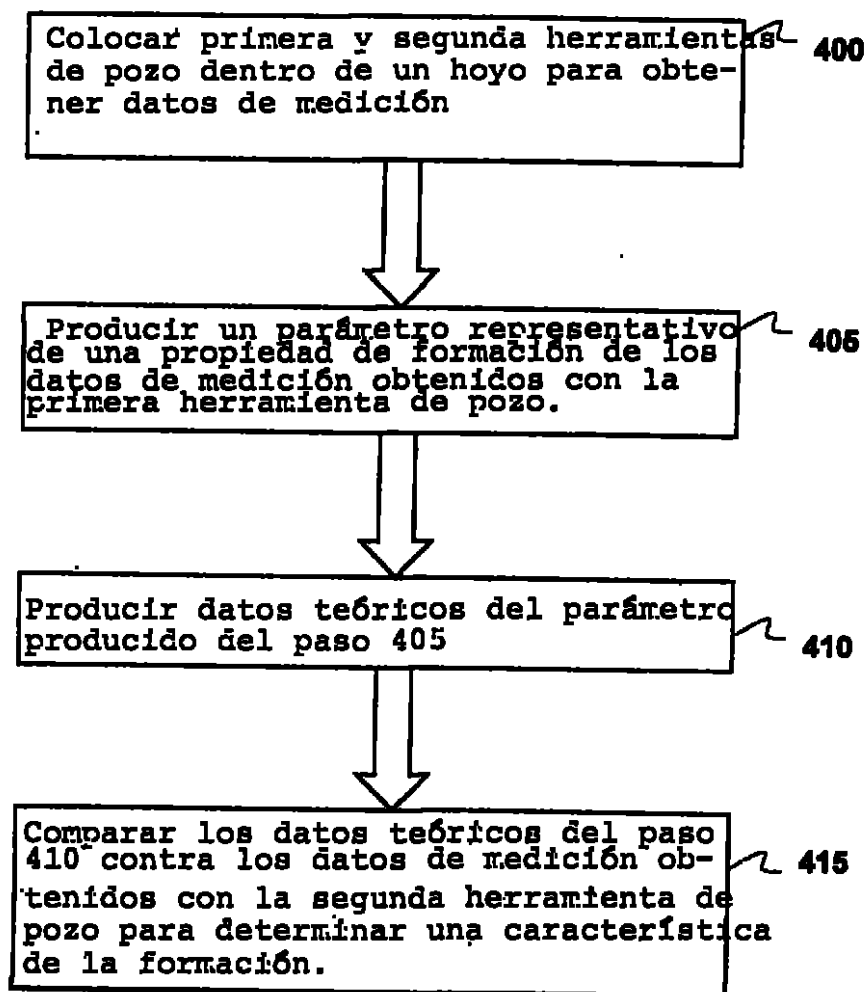
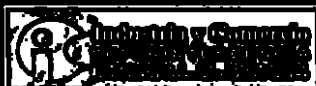


FIG. 21

116



FORMATO DE DIGITALIZACION
RELACION DE ANEXOS



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Expediente No		No de unidades	No de Folios
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8	SOBRE BLANCO TAMAÑO CARTA		
9	SOBRE BLANCO TAMAÑO OFICIO X	1	✓
10	OTROS:		

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un sobre q1 contiene
arte final



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5. at Austin, Texas

6. on August 13, 2001

7. by the Secretary of State of Texas

8. Certificate No. N-262235

9. Seal

10. Signature:



Henry Cuellar
 Henry Cuellar
 Secretary of State
 ST/VA

INVENTION ASSIGNMENT

The undersigned Thomas D. Barber

Domiciled in Houston, Texas U.S.A.

Hereby appoint(s) Dr. GERMAN CASTILLO GRAU, and/or Dr. ADRIANA CASTILLO GIBSON and/or Dr. LUIS FELIPE CASTILLO GIBSON, domiciled in Bogota, Colombia, with offices at Carrera 13 No. 37 - 43, 12th Floor in Bogota, as attorney with ample and sufficient power, including that of receiving notifications and appointing judicial and extra-judicial attorneys, to apply for and obtain from the Colombian offices and authorities the Patent of Invention for **METHOD AND SYSTEM FOR INDICATING ANISTROPIC RESISTIVITY IN AN EARTH FORMATION** to be issued in the name of SCHLUMBERGER HOLDINGS LIMITED domiciled in the British Virgin Islands to whom assignment has been made of all rights and titles on said invention/creation without any restriction whatsoever.

Given and signed in Houston, Tx

Inventor(s)

Thomas D. Barber

County of Fort Bend

State of Texas

Subscribed and sworn to before me this 10th day of August, 2001.

Rose Ann Tidel
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Patrick O. Hatchett

Patrick O. Hatchett

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APPLICATION NUMBER: 09/585,761

FILING DATE: June 02, 2000



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Schlumberger

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09/585761

Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

Docket No.: 20.2743
Total Pages = 44

Re: Application of: Schlumberger Technology Corporation
For: Method and System for Indicating Anisotropic Resistivity in an Earth Formation
Full Names of Inventor(s): Thomas D. Barber

- ☒ 37 CFR 1.53(b) UTILITY PATENT APPLICATION TRANSMITTAL, or
☐ 37 CFR 1.53(b) CONTINUING APPLICATION OF PRIOR APPLICATION
 NO. _____
☐ Continuation
☐ Divisional
☐ Continuation-in-part (CIP)

In accordance with 37 CFR 153(b) enclosed are:

- 1 ☒ Fee Transmittal Form (Original & Duplicate)= 4
 2 ☒ Patent Application Total No. Pages = 18
 3a ☐ Informal Drawings Total No. Pages =
 3b ☒ Formal Drawings Total No. Pages = 15
 4 ☒ Oath or Declaration Total No. Pages = 3 (Includes Power of Attorney)
 4a ☒ Newly Executed (Original or Copy)
 4b ☐ Copy from Prior Application (37 CFR 1.63(d)) for Continuation/Divisional noted above
 4c ☐ Deletion of Inventors (Signed Statement Deleting Inventors Named in Prior Application
 37 CFR 1.63(d)(2) and 1.33(b)
 5 ☐ Incorporation by Reference (Usable if 4b is checked) Entire Disclosure of Prior Application, from
 which a copy of the oath for declaration is supplied is considered as being part of the disclosure of the
 accompanying application and is hereby incorporated by reference therein
 6 ☐ Amend the specification by inserting before the first line the sentence:
 This is a ☐ continuation ☐ continuation-in-part ☐ division of
 application serial no. _____ filed _____
 7 ☐ The prior application is assigned to SCHLUMBERGER TECHNOLOGY CORPORATION.

Accompanying Application Parts

- 6 ☒ Assignment Papers (Cover Sheet & duplicate & document(s))= 4
 7 ☐ 37 CFR 3.73(b) Statement
☐ Power of Attorney
 8 ☒ Information Disclosure Statement (IDS) PTO-1449
☒ 8 Copies of Citations
 9 ☐ Preliminary Amendment
 10 ☒ Return Receipt Postcard (MPRP 503)
 11 ☐ English Translation Document
 12 ☐ Certified Copy of Priority Document (if Foreign Priority is Claimed)
 13 ☐ Other:

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CLAIMS AS FILED				
(1) FOR	(2) NUMBERS FILED	(3) NUMBER EXTRA	(4) RATE	(5) TOTAL
BASIC FEE				\$690
TOTAL CLAIMS	26 - 20 =	6	x\$18	\$108
INDEPENDENT CLAIMS	4 - 3 =	1	x\$78	\$78
ADDITIONAL FEE FOR FILING ONE OR MORE MULTIPLE DEPENDENT CLAIMS \$260				
TOTAL FILING FEE				\$876
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Date: 2-JUN-00

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PATENT
20.2743

APPLICATION FOR UNITED STATES LETTERS PATENT

for

Method and System for Indicating Anisotropic Resistivity
in an Earth Formation

by

Thomas D. Barber

09585761.060200

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<u><i>Debra L. Browning</i></u> Debra L. Browning	

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METHOD AND SYSTEM FOR INDICATING ANISOTROPIC RESISTIVITY IN
AN EARTH FORMATION

1. BACKGROUND OF THE INVENTION

1.1 Field of the Invention

The present invention is generally directed to the analysis of underground earth formations, and, more particularly, to the determination of formation resistivity properties and/or profiles.

1.2 Description of Related Art

Knowledge of the resistivity properties of underground earth formations is fundamental in the evaluation and characterization of potential and existing hydrocarbon-bearing reservoirs. The terms "logging" and "log" are respectively used herein to designate any sequential measurements and the recording of such measurements as a function of depth and/or time of variations in a given characteristic of the formations around a borehole.

Formation resistivity anisotropy is a characteristic of reservoirs that can complicate formation evaluation. Many reservoir rocks exhibit resistivity anisotropy, especially when saturated with oil. There are several mechanisms, which can produce this anisotropy, among which are very thin sand-shale laminations, depositional changes in clean sandstone, and wind-distributed sands (aeolian formations). See Rubin, D. M., *Cross bedding, bedforms, and paleocurrents*, SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS, CONCEPTS IN SEDIMENTOLOGY AND PALEONTOLOGY, 1; Klein et al., *The petrophysics of electrically anisotropic reservoirs*, Transactions of the SPWLA THIRTY-SIXTH ANNUAL LOGGING SYMPOSIUM, Paris, France, June 26-29, 1995, paper HH. Resistivity measurements from within a borehole drilled through these formations have been made by a number of techniques employing the use of well-known instruments, including induction and laterolog (electrode) type devices.

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In induction logging, a transmitter coil mounted on a well tool is lowered into a borehole and energized by an alternating current. Indications are then obtained of the influence of surrounding formations on the electromagnetic field established by the coil. Usually such indications are obtained by observing the voltage induced in a receiver coil also mounted on the well tool in coaxial relationship with the transmitter coil and axially spaced apart therefrom. Conventional induction well tools include at least one transmitter and a receiver coil array. Such an induction tool is illustrated and described in U.S. Pat. No. 5,157,605, assigned to the present assignee.

The laterolog technique comprises making a measurement with a well tool having a current emitting electrode and voltage electrodes one either side thereof which are operated to force current into the formation. The current is focused into the formations and returns locally, i.e., to the tool body. The formation resistivity is determined by measuring the current flow. Conventional laterolog tools are illustrated and described in U.S. Pat. Nos. 5,754,050, 5,852,363, 6,023,168, and Documents EP-478409, EP-544583, all assigned to the present assignee. Document EP-544583 describes a laterolog tool including both a "deep" investigation mode and a "shallow" (LLS) investigation mode.

The sensitivity of a resistivity logging tool to resistivity anisotropy depends on the physics of the measurement and the relative dip angle of the well bore of the formation. For example, 2MHz induction-type tools have no sensitivity to resistivity anisotropy when the formation layers are perpendicular to the well bore, but will be quite sensitive at relative dip angles above 60 degrees. See Lilling et al., *Processing and modeling 2 MHz resistivity tools in dipping, laminated, anisotropic formations*, Transactions of the SPWLA THIRTY-FIFTH ANNUAL LOGGING SYMPOSIUM, Tulsa, Oklahoma, June 19-22, 1994, paper QQ.

Induction logging tools are insensitive to resistivity anisotropy at low relative dip. The current density set up in the formation is limited to the horizontal direction. See Moran et al., *Effects of formation anisotropy on resistivity-logging measurements*, GEOPHYSICS, V. 44, No. 7, July 1979, 1266-86; Anderson et al., *The Response of*

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Induction Tools to Dipping Anisotropic Formations, Transactions of the SPWLA THIRTY-SIXTH ANNUAL LOGGING SYMPOSIUM, Paris, France, June 26-29, 1995, paper D. At higher relative dips the measured resistivity will combine both vertical and horizontal components. However, this effect does not depend on the coil array spacing, so the components are not resolvable. See Anderson et al., *The Response of Induction Tools to Dipping Anisotropic Formations*, Transactions of the SPWLA THIRTY-SIXTH ANNUAL LOGGING SYMPOSIUM, Paris, France, June 26-29.

Laterolog logging tools have some sensitivity to the vertical component of resistivity. See Moran et al., *Effects of formation anisotropy on resistivity-logging measurements*, GEOPHYSICS, V. 44, No. 7, July 1979, 1266-86; Chemali et al., *The effect of shale anisotropy on focused resistivity devices*, Transactions of the SPWLA TWENTY-EIGHTH ANNUAL LOGGING SYMPOSIUM, London, England, June 30-July 2, 1987, paper H. However, with the dual-laterolog, the deep laterolog was not very sensitive to anisotropy. The shallow laterolog, which returns current to nearby electrodes, is more sensitive to anisotropy (See Moran et al., 1979), but invasion will reduce the effect of anisotropy.

It is desirable to obtain a reliable method and system for determining the resistivity properties and profiles of potential hydrocarbon-bearing zones in subsurface formations. Thus, there remains a need for improved methods and techniques to indicate formation resistivity anisotropy and evaluate the vertical component of resistivity.

2. SUMMARY OF THE INVENTION

Methods and systems are disclosed for combining induction tool and laterolog tool measurements to indicate that the formation resistivity is anisotropic and estimate the vertical component of resistivity even in the presence of invasion.

One aspect of the invention provides a method for determining a characteristic of a subsurface earth formation surrounding a borehole. The method comprises calculating at least one parameter representative of a property of the formation using log data obtained with a first well tool disposed within the borehole; modeling log data from the at least one calculated parameter; and comparing log data obtained with a second well tool

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disposed within the borehole against the modeled log data to determine the formation characteristic.

Another aspect of the formation provides a method for determining a characteristic of a subsurface earth formation surrounding a borehole. The method comprises disposing first and second well tools within the borehole to obtain measurement data; producing at least one parameter representative of a property of the formation from the measurement data obtained with the first well tool; producing theoretical data from the at least one produced parameter, and comparing the theoretical data against the measurement data obtained with the second well tool to determine the formation characteristic.

Another aspect of the invention provides a well logging system including first and second well tools adapted to be moveable through a borehole and an apparatus adapted to be coupled to the well tools, the apparatus being adapted to respond to data obtained with the well tools to determine a characteristic of a formation. The apparatus comprises means for calculating at least one parameter representative of a property of the formation using log data obtained with the first well tool disposed within the borehole; means for modeling log data from the at least one calculated parameter; and means for comparing log data obtained with the second well tool disposed within the borehole against the modeled log data to determine the formation characteristic.

Yet another aspect of the invention provides a program storage device readable by a processor and encoding a program of instructions including instructions for performing operations in accord with the invention.

3. BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

Figure 1 is a schematic diagram of the laterolog energization patterns obtained with a conventional laterolog tool.

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Figure 2 is a schematic diagram of the current lines corresponding to the laterolog patterns of Figure 1.

Figure 3 is a graph showing the response of the five laterolog arrays of Figures 1 and 2 in a homogeneous anisotropic formation.

Figures 4-7 are graphical illustrations of the responses of the five laterolog arrays of Figures 1 and 2 in invaded, anisotropic formations.

Figure 8 is a graph showing the comparison of a laterolog tool response in an anisotropic formation vs. its response in an isotropic formation in accord with the invention.

Figure 9 illustrates several plots of a ratio used in the calculations of the invention.

Figure 10 illustrates the ratio plots of Figure 9 with an applied scaling factor.

Figure 11 shows a crossplot for seventy ratios pertaining to cases of formation parameters in accord with the invention.

Figure 12 shows an average value of a parameter for the ratios of Figure 11 in accord with the invention.

Figure 13 is a graph showing a computed formation vertical resistivity component in accord with the invention.

Figure 14 is a graph showing computed induction tool and laterolog tool logs in accord with the invention.

Figure 15 is a graph showing the inversion of the induction tool data of Figure 14 using a laterolog model in accord with the invention.

Figure 16 is a graph showing the vertical resistivity component derived from the data of Figures 14 and 15 in accord with the invention.

Figure 17 shows field logs obtained from an induction tool and a laterolog tool in accord with the invention.

Figure 18 shows the vertical resistivity component derived from the data of Figure 17 in accord with the invention.

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Figure 19 is a schematic diagram of a well logging system in accord with the invention.

Figure 20 is a flow diagram of a method in accord with the invention.

Figure 21 is a flow diagram of another method in accord with the invention.

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4. DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

In the interest of clarity, not all features of actual implementation are described in this specification. It will be appreciated that although the development of any such actual implementation might be complex and time-consuming, it would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Figure 1 shows the energization patterns, referred to as "laterologs", obtainable from a laterolog-type tool 10 such as those disclosed in U.S. Pat. Nos. 5,754,050, 5,852,363, 6,023,168, and Document EP-478409. The deepest array, mode 5, is considerably deeper than the LLS and should have considerable sensitivity to anisotropy. Figure 2 shows the current paths on several of the arrays of the tool 10. Note that the current flow lines turn parallel to the tool 10 axis and return locally, thereby increasing the sensitivity to the vertical resistivity component.

Figure 3 shows the response of the tool 10 arrays (1-5) to an anisotropic homogeneous formation. The ratio of the apparent resistivity R_{app} over the formation horizontal resistivity component R_h is plotted against the ratio of the formation vertical resistivity component R_v over R_h . This separation shows that the shallow arrays are much more sensitive to an anisotropic formation than the deeper arrays. Although the homogeneous medium anisotropy response looks favorable, what really matters is the response in the presence of invasion.

Figures 4 through 7 show four representative cases of formation resistivity measurements obtained with a laterolog tool in an anisotropic formation having invasion out to a radius of 60 inches. These figures show ratios of the formation horizontal resistivity component R_{th} over the formation invasion resistivity R_{xo} of 0.1, 0.2, 5, and

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10. For all the cases $R_{tv} = 10 \times R_{th}$. The invaded zone is isotropic with resistivity R_{xo} . In Figures 4 and 5, $R_{xo} > R_{th}$. In Figures 6 and 7, $R_{xo} < R_{th}$. For all these cases, the invasion response confuses the anisotropy response.

Figure 8 shows the anisotropic case of Figure 7 superimposed with the laterolog tool response to an isotropic virgin zone with formation resistivity R_t equal to R_{th} . As seen in Figure 8, the two curves representing Array 5 (RLA5) are almost parallel over the range of invasion radius out to 60 inches. The other shallower isotropic-vs.-anisotropic cases show separation at shallow invasion, but little or no separation at deeper invasion radii. The reasonable constancy of the difference between the isotropic and anisotropic Array 5 response suggests that the ratio of anisotropic to isotropic response or other ratios provide useful information.

Designating R_{aa} as the laterolog Array 5 log in an anisotropic formation, and R_{ai} as the laterolog Array 5 log reading in an isotropic formation, the following ratio is derived:

$$\frac{R_{ai}}{(R_{aa} - R_{ai})}$$

Figure 9 shows a plot of the above ratio for $R_{xo} = 1$ and $R_{th} = 10$ for λ values from 1.4 to 10, where

$$\lambda = \sqrt{\frac{R_{tv}}{R_{th}}}$$

It should be noted that the spread is almost proportional to λ . This suggests that the ratio

$$\frac{\lambda R_{ai}}{R_{aa} - R_{ai}}$$

should be nearly constant. This ratio is shown in Figure 10.

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If the ratio

$$A = \frac{\lambda R_{ai}}{(R_{aa} - R_{ai})} \quad (1)$$

is nearly constant for this case, then other values of R_{xo} and R_{th} should be looked at. Figure 11 shows a crossplot of 7 combinations of R_{xo} and R_{th} . There are 10 values of λ ranging from 1.4 to 10. The spread in A is remarkably small. Figure 12 shows the average value of A from the data of Figure 11. If an average value of A is taken to be a constant (or fitted function of the radius of invasion r_i), then the unknown λ can be solved for

$$\lambda = A \frac{(R_{aa} - R_{ai})}{R_{ai}} \quad (2)$$

One unknown remains in equation (2) — R_{ai} .

As mentioned above, induction tools have little or no sensitivity to R_{tv} in a vertical well. In such a case, the induction tool log data is inverted for R_{xo} , R_{th} , and r_i using a lookup table, computer algorithm, model, or any other inversion means as known in the art. Also known in the art is the use of modeling techniques to simulate specific tool responses from given data. By applying a one-dimensional (1D) model of the laterolog tool response to the formation parameters obtained from the induction tool, R_{xo} , R_{th} , and r_i , the laterolog log data in an isotropic formation (R_{ai}) can be inferred.

Then equation (2) can be solved for λ , and then

$$R_{tv} = \lambda^2 R_{th} \quad (3)$$

Figure 13 shows such a solution using a fitted value of A as a function of r_i . The values for A may be precomputed. The value for A 1D model for the laterolog tool was derived using a simple average J -function, which is only a gross estimate for an example. The estimate of R_{tv} is within a factor of 2 of the actual value of R_{tv} in the uninvaded zone. Although a factor of 2 may be considered inaccurate for estimates of petrophysical quantities, such accuracy is ample for determining that anisotropy exists in a vertical well.

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The accuracy may be improved by refining A . Both induction and laterolog tools have effects in 2D formations (layers and invasion in the layers) that are not accurately modeled with 1D forward models. To test the usefulness of the 1D models used in the recreation of R_{ai} , it is advisable to try the algorithm in a 2D-formation model.

Figure 14 shows computed induction and laterolog tool logs in a simple 2D formation with 3 invaded, anisotropic layers of varying thickness. These layers have identical values of R_{tv} , R_{th} , R_{xo} , and r_l . The thickness varies from 50 ft. to 10 ft. The induction tool log data reflects the receiver to transmitter spacings (10 in.- 90 in.) for the particular tool.

Figure 15 shows a modeled laterolog tool log derived from the induction tool log data of Figure 14. The modeled log data represents the theoretical log values obtainable with the laterolog tool disposed within the isotropic formation. The modeled laterolog log data are then compared against the actual or apparent laterolog log data to compute R_{tv} as described above. Figure 16 shows the resulting R_{tv} log computed from the data of Figures 14 and 15.

The R_{tv} log of Figure 16 shows anomalies in the non-invaded isotropic beds between the invaded anisotropic beds. As seen in Figure 14, the laterolog tool logs display shoulder effect in these beds and on either side of the first and third beds. Any source of error that leads to an increased separation between the laterolog tool logs predicted from the induction tool parameters and apparent laterolog tool logs will be interpreted as anisotropy. Overall, however, intelligent interpretation should remove most ambiguity.

A field test was conducted comparing a laterolog tool against an induction tool in a formation with expected resistivity anisotropy. Figure 17 shows the induction tool and laterolog tool logs in a pay sand. Figure 18 shows the indicated vertical resistivity R_{tv} along with the induction tool R_{th} , R_{xo} , and r_l inversion in a zone that exhibits the anisotropy signature. It also exhibits shoulder effect just as in the computed example of Figure 16.

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4.1 Program Storage Device

It will be apparent to those of ordinary skill having the benefit of this disclosure that the present invention may be implemented by programming one or more suitable general-purpose computers having appropriate hardware. The programming may be accomplished through the use of one or more program storage devices readable by the computer processor and encoding one or more programs of instructions executable by the computer for performing the operations described above. The program storage device may take the form of, e.g., one or more floppy disks; a CD ROM or other optical disk; a magnetic tape; a read-only memory chip (ROM); and other forms of the kind well-known in the art or subsequently developed. The program of instructions may be "object code," i.e., in binary form that is executable more-or-less directly by the computer; in "source code" that requires compilation or interpretation before execution; or in some intermediate form such as partially compiled code. The precise forms of the program storage device and of the encoding of instructions are immaterial here.

4.2 Logging System

The present invention can be implemented in a logging system 200 with a first well tool 210 and a second well tool 215 adapted to be moveable through a borehole and an apparatus 220 coupled to the tools as shown in Figure 19. Certain conventional details are omitted in Figure 19 for clarity of illustration. The apparatus 220 comprises a surface computer (such as the general-purpose computer and program storage device described above) coupled to the well tools 210, 215 by a wireline cable 225 or linked to the tool string's surface instrumentation as known in the art.

The first well tool 210 may be any laterolog-type tool that returns current locally, i.e., to the sonde body. The second well tool 215 may be any propagation or induction tool that provides multiple curves, preferably providing at least three independent measurements to solve for R_{xo} , R_t , and r_l . In addition to the U.S. Patents mentioned above, other useable tools include the instruments described and illustrated in U.S. Pat. Nos. 5,339,037 and 4,968,940, both assigned to the present assignee.

The formation parameters can be determined in real-time by sending the measurement data to the surface as they are acquired, or it can be determined from a recorded-mode by recording the data on a suitable recordable medium. As known in the art, the measured data are transmitted from the tools 210, 215 to the surface computer 220 by electronics (not shown) housed in the tools. The data may be sent to the surface computer 220 along the wireline cable 225 or by mud-pulse telemetry if implemented in a logging-while-drilling configuration. It will be understood that alternative means can be employed for communicating the acquired data to the surface as the precise form of communication is immaterial to the implementation of the disclosed techniques.

Once received by the surface computer 220, the data can be recorded, processed, or computed as desired by the user to generate the formation resistivity profile. The profile can then be recorded on a suitable output record medium. Alternatively, some or all of the processing can be performed downhole and the data can be recorded uphole, downhole, or both. It will be understood that the present invention can be implemented in conjunction with any suitable technique for keeping track of the tool 210, 215 depth within a borehole.

Figure 20 illustrates a flow diagram of a method for determining a characteristic of a subsurface formation surrounding a borehole in accord with the invention. The method comprises calculating at least one parameter representative of a property of the formation using log data obtained with a first well tool disposed within the borehole 300; modeling log data from the at least one calculated parameter 305; and comparing log data obtained with a second well tool disposed within the borehole against the modeled log data to determine the formation characteristic 310.

Figure 21 illustrates a flow diagram of a method for determining a characteristic of a subsurface formation surrounding a borehole in accord with the invention. The method comprises disposing first and second well tools within the borehole to obtain measurement data 400; producing at least one parameter representative of a property of the formation from the measurement data obtained with the first well tool 405; producing theoretical data from the at least one produced parameter 410; and comparing the

produced the retinal data against the measurement; data obtained with the second well tool to determine the formation characteristic 415.

While the methods and apparatus of this invention have been described as specific embodiments, it will be apparent to those skilled in the art that variations may be applied to the structures and in the steps or in the sequence of steps of the methods described herein without departing from the concept and scope of the invention. All such similar variations apparent to those skilled in the art are deemed to be within this concept and scope of the invention as defined by the appended claims.

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WHAT IS CLAIMED IS:

1. A method for determining a characteristic of a subsurface earth formation surrounding a borehole, comprising:
 - (a) calculating at least one parameter representative of a property of the formation using log data obtained with a first well tool disposed within the borehole;
 - (b) modeling log data from the at least one calculated parameter; and
 - (c) comparing log data obtained with a second well tool disposed within the borehole against the modeled log data to determine the formation characteristic.
2. The method of claim 1, wherein step (b) comprises modeling log data representative of log data theoretically obtainable with the second well tool disposed within the borehole.
3. The method of claim 1, wherein step (c) comprises calculating a ratio between the log data obtained with the second well tool and the modeled log data.
4. The method of claim 1, wherein step (c) comprises calculating the difference between the log data obtained with the second well tool and the modeled log data.
5. The method of claim 4, wherein step (c) comprises multiplying the calculated difference by a predetermined factor.
6. The method of claim 1, wherein the first well tool is an induction-type tool.
7. The method of claim 1, wherein the second well tool is a laterolog-type tool.
8. The method of claim 1, wherein the determined formation characteristic is a resistivity value or resistivity profile.

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- 1 9. The method of claim 1, wherein the method is performed during or after drilling
2 of the borehole.
3
- 4 10. A method for determining a characteristic of a subsurface earth formation
5 surrounding a borehole, comprising:
6 (a) disposing first and second well tools within the borehole to obtain
7 measurement data;
8 (b) producing at least one parameter representative of a property of the
9 formation from the measurement data obtained with the first well tool;
10 (c) producing theoretical data from the at least one produced parameter of step
11 (b); and
12 (d) comparing the theoretical data of step (c) against the measurement data
13 obtained with the second well tool to determine the formation
14 characteristic.
15
- 16 11. The method of claim 10, wherein step (c) comprises producing theoretical data
17 representative of measurement data obtainable with the second well tool disposed
18 within the borehole.
19
- 20 12. The method of claim 10, wherein step (d) comprises calculating a ratio between
21 the measurement data obtained with the second well tool and the produced
22 theoretical data.
23
- 24 13. The method of claim 10, wherein step (d) comprises calculating the difference
25 between the measurement data obtained with the second well tool and the
26 produced theoretical data.
27
- 28 14. The method of claim 13, wherein step (d) comprises multiplying the calculated
29 difference by a predetermined factor.
30

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- 1 15. The method of claim 10, wherein the first well tool is an induction-type tool.
- 2
- 3 16. The method of claim 10, wherein the second well tool is a laterolog-type tool.
- 4
- 5 17. The method of claim 10 wherein the determined formation characteristic is a
- 6 resistivity value or resistivity profile.
- 7
- 8 18. The method of claim 10, wherein the method is performed during or after drilling
- 9 of the borehole.
- 10
- 11 19. A well logging system including first and second well tools adapted to be
- 12 moveable through a borehole and an apparatus adapted to be coupled to the well
- 13 tools, the apparatus being adapted to respond to data obtained with the well tools
- 14 to determine a characteristic of a formation, the apparatus comprising:
- 15 means for calculating at least one parameter representative of a property of the
- 16 formation using log data obtained with the first well tool disposed within
- 17 the borehole;
- 18 means for modeling log data from the at least one calculated parameter; and
- 19 means for comparing log data obtained with the second well tool disposed
- 20 within the borehole against the modeled log data to determine the
- 21 formation characteristic.
- 22
- 23 20. The system of claim 19, the modeling means further comprising means for
- 24 modeling log data that is representative of log data theoretically obtainable with
- 25 the second well tool disposed within the borehole.
- 26
- 27 21. The system of claim 19, the comparison means further comprising means for
- 28 calculating a ratio between the log data obtained with the second well tool and the
- 29 modeled log data.

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- 1 22. The system of claim 19, the comparison means further comprising means for
2 calculating the difference between the log data obtained with the second well tool
3 and the modeled log data.
4
- 5 23. The system of claim 19, wherein the first well tool is an induction-type tool.
6
- 7 24. The system of claim 19, wherein the second well tool is a laterolog-type tool.
8
- 9 25. The system of claim 19, wherein the determined formation characteristic is a
10 resistivity value or resistivity profile.
11
- 12 26. A program storage device readable by a processor and encoding a program of
13 instructions including instructions for performing the apparatus operations recited
14 in claim 19.

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ABSTRACT

A system and methods for indicating formation resistivity anisotropy and evaluating the vertical resistivity component by combining array induction measurements and array laterolog measurements. Formation measurements are obtained with an induction tool and a laterolog tool. Formation parameter data are derived from the induction tool measurements. The laterolog tool response is modeled using the derived formation parameter data. The formation resistivity anisotropy and/or the vertical resistivity component are determined from a comparison of the modeled laterolog tool response against the apparent measurements obtained with the laterolog tool.

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DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, and

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND SYSTEM FOR INDICATING ANISOTROPIC RESISTIVITY IN AN EARTH FORMATION

the specification of which

☒ is attached hereto.

☐ was filed on _____

as Application Serial Number _____

or PCT International Application Number _____

and was amended on (if applicable) _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate or of any PCT international application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

(Number) (Country)

/ / /
D/M/YR FILED

☐ YES ☐ NO

(Number) (Country)

/ / /
D/M/YR FILED

☐ YES ☐ NO

(Number) (Country)

/ / /
D/M/YR FILED

☐ YES ☐ NO

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I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below:

Application No. _____

Filing Date _____

Application No. _____

Filing Date _____

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT International filing date of this application:

Application
Serial No. _____

Filing
Date _____

Status-patented, pending,
abandoned _____

Application
Serial No. _____

Filing
Date _____

Status-patented, pending,
abandoned _____

As a named inventor, I hereby appoint the following attorney(s) and/or agents(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

J. J. Ryberg, #31,134; Brigitte L. Jeffery, #38,925; Steven L. Christian, #38,106 and Victor H. Segura, #44,329. I hereby request that all correspondence, notices, official letters and other communication be directed to Schlumberger Technology Corporation, ATTN: IP Counsel, P. O. BOX 2175, Houston, Texas 77252-2175; and that all telephone calls be directed to: Steven L. Christian, at (281) 285 8809, Schlumberger Oilfield Services, P. O. BOX 2175, Houston, Texas 77252-2175. Schlumberger U.S. PTO Customer No. is 23718.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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SOLE OR FIRST INVENTOR

Signature Thomas D. Barber Date June 2, 2000.

Full Name: Thomas D. Barber

Residence: 6324 Westchester, Houston, Texas 77005 USA

Citizenship: USA

P.O. Address: 6324 Westchester, Houston, Texas 77005 USA

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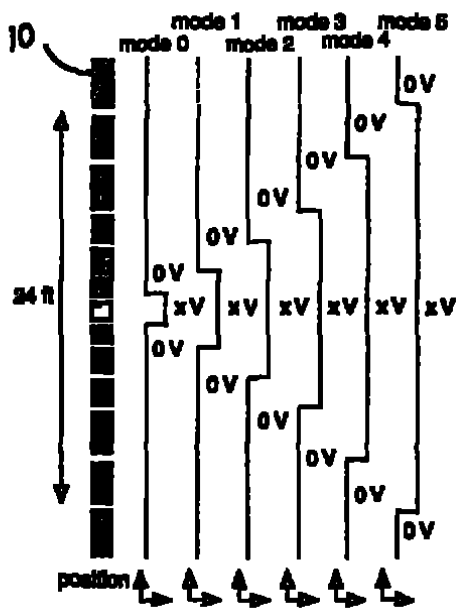


FIG. 1

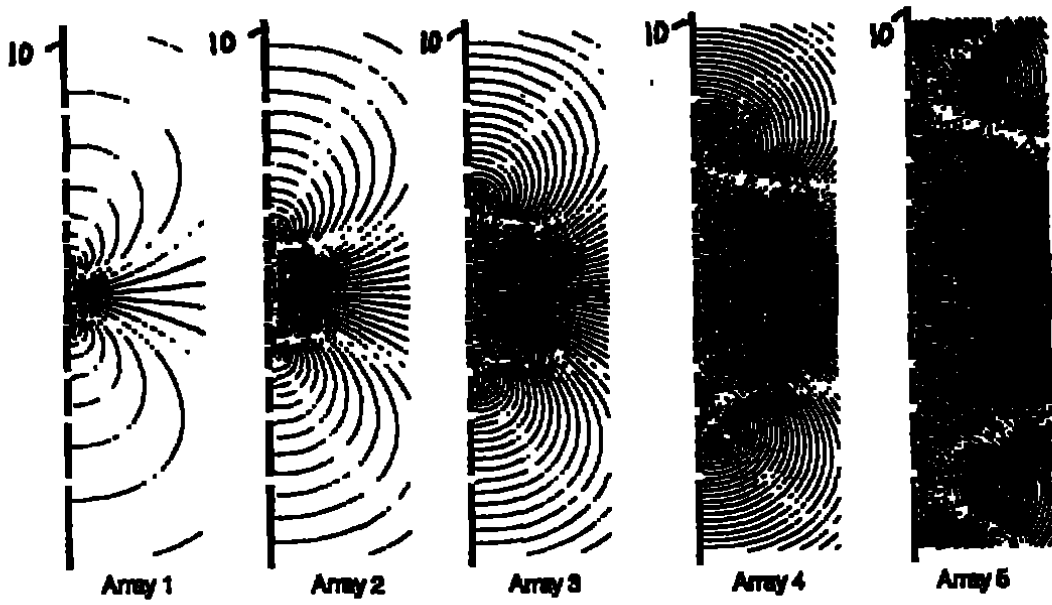


FIG. 2

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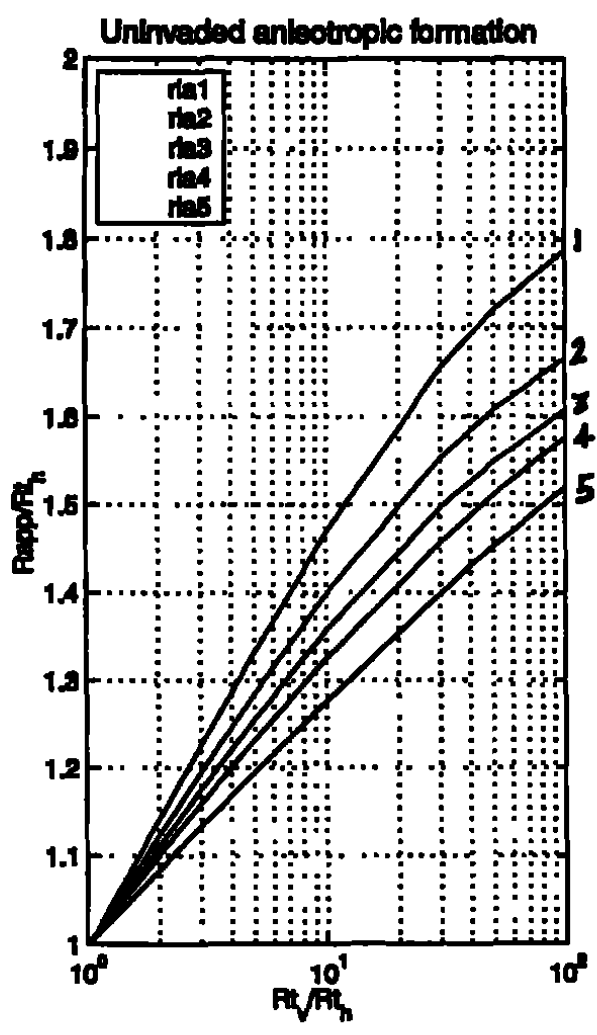


FIG. 3

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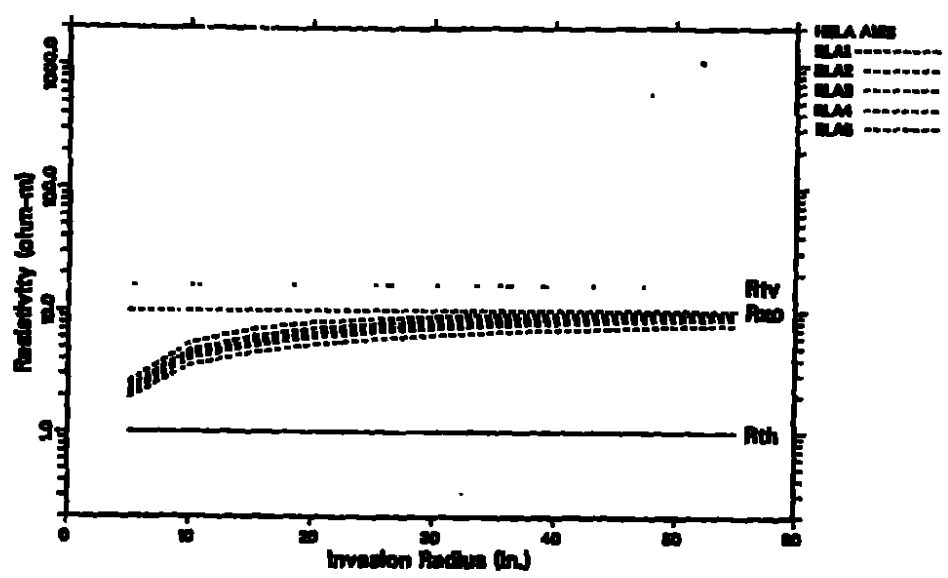


FIG. 4

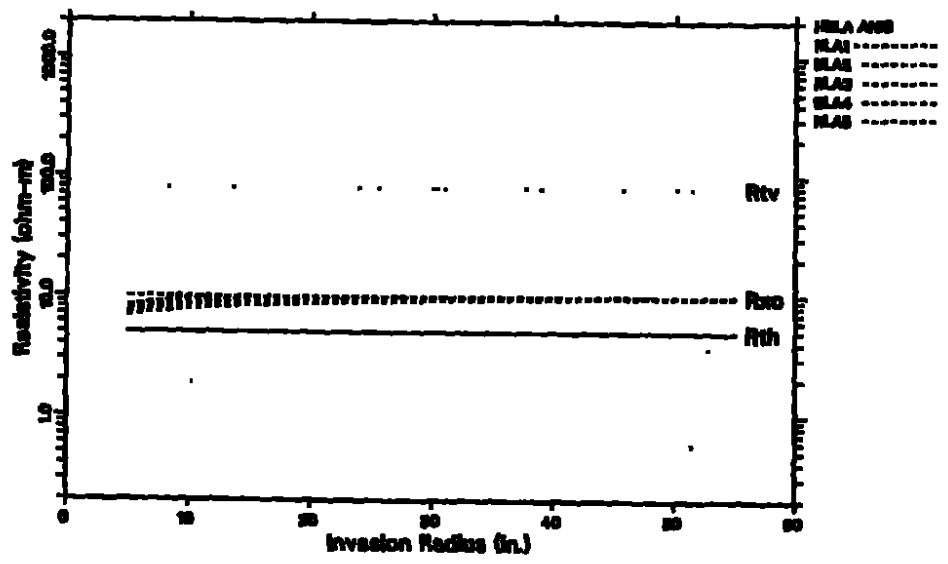


FIG. 5

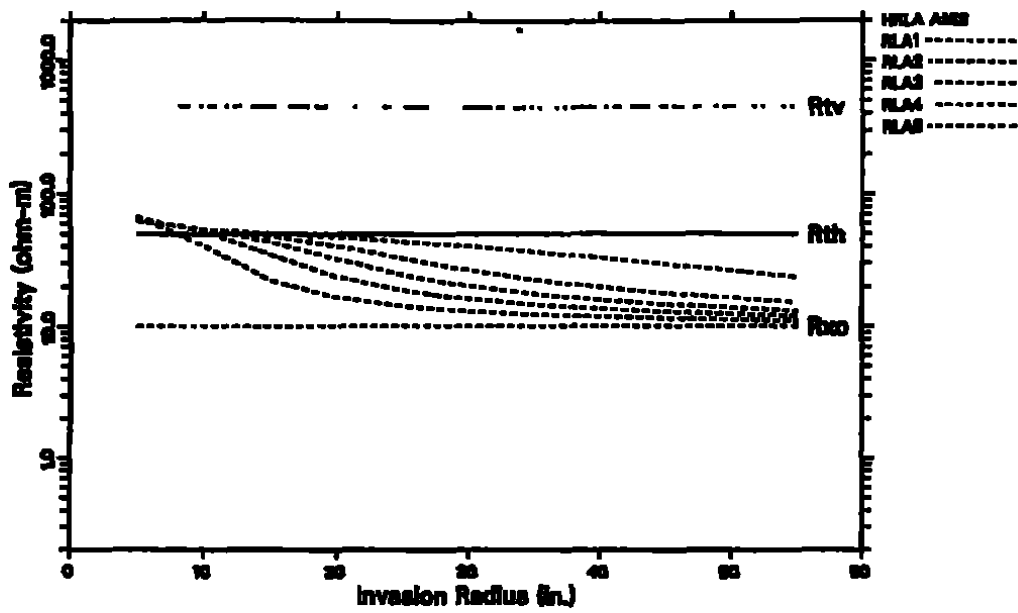


FIG. 6

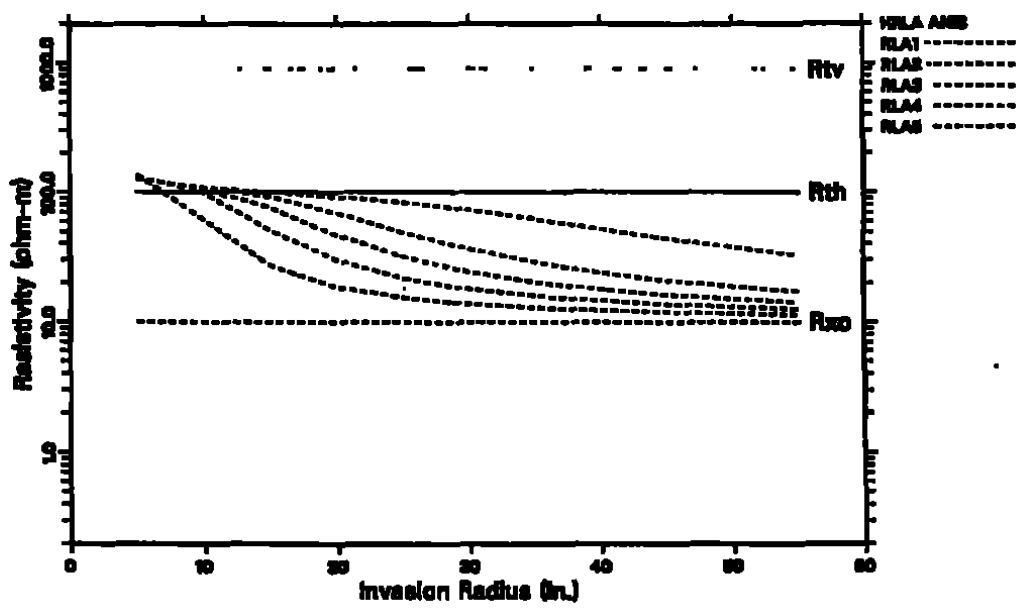


FIG. 7

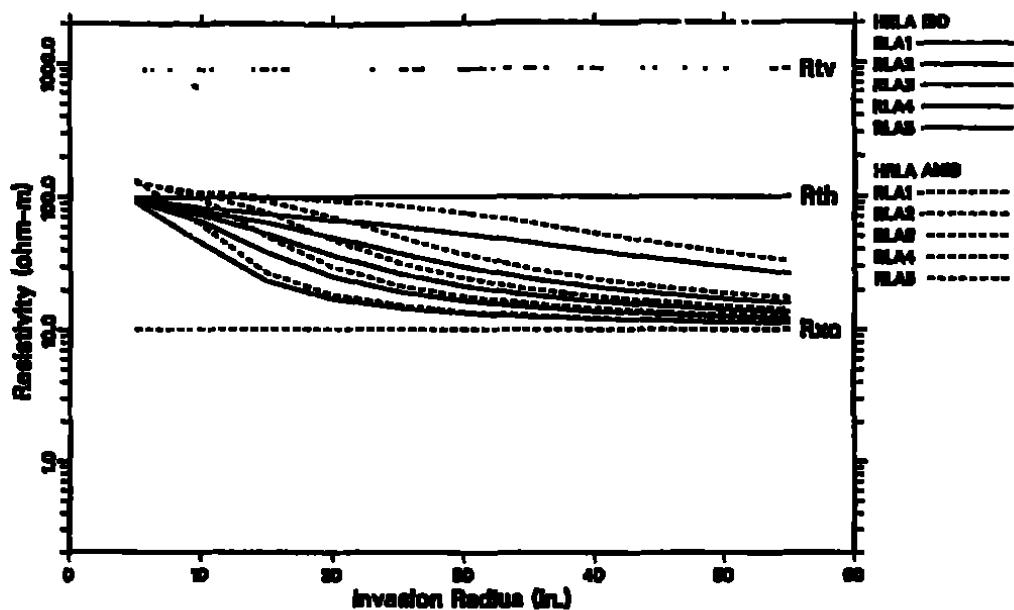


FIG. 8

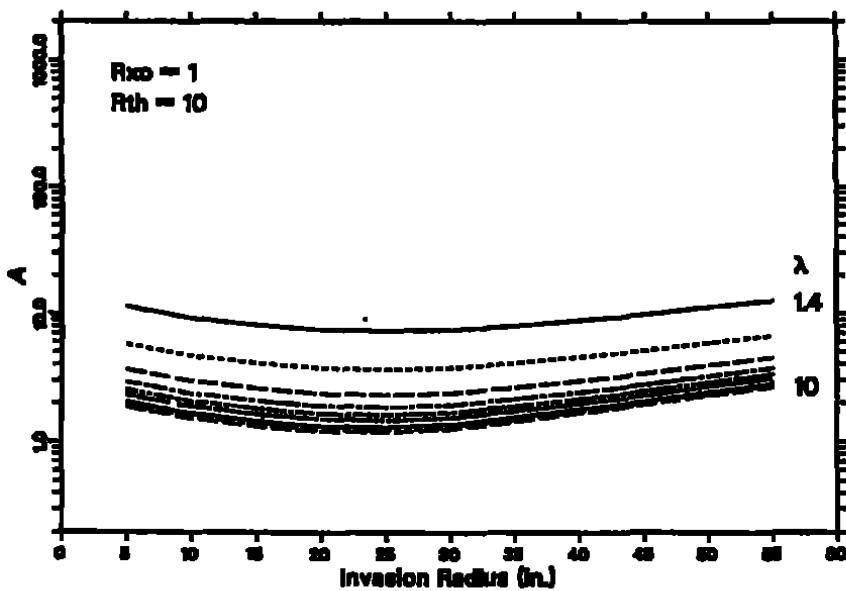


FIG. 9

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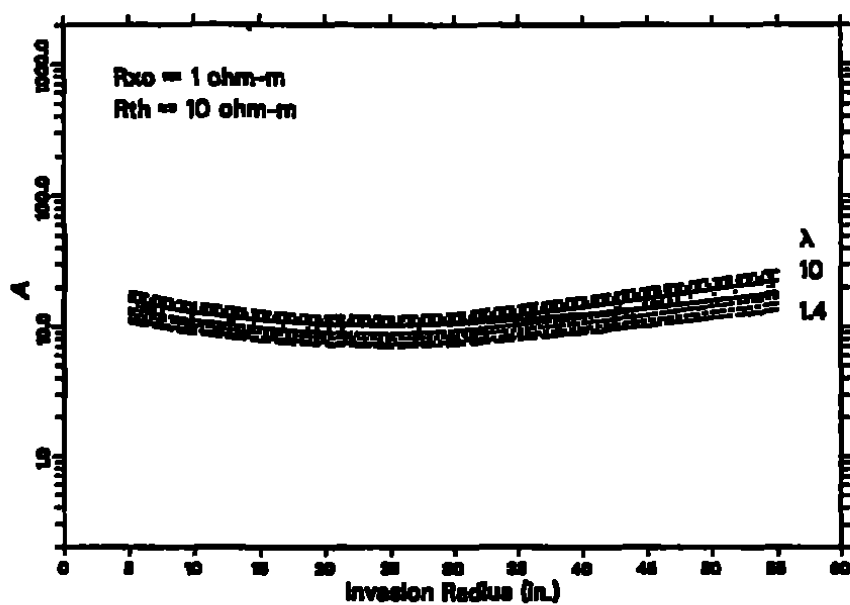


FIG. 10

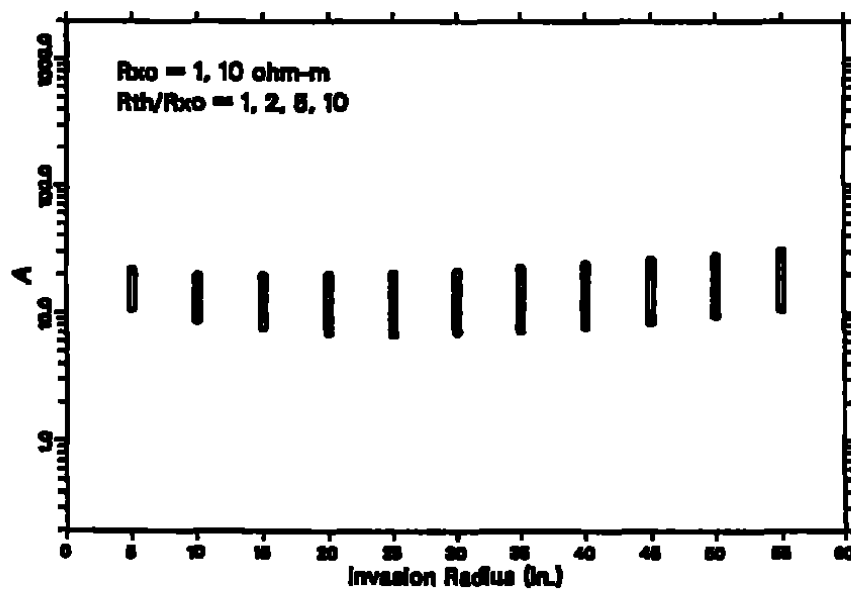
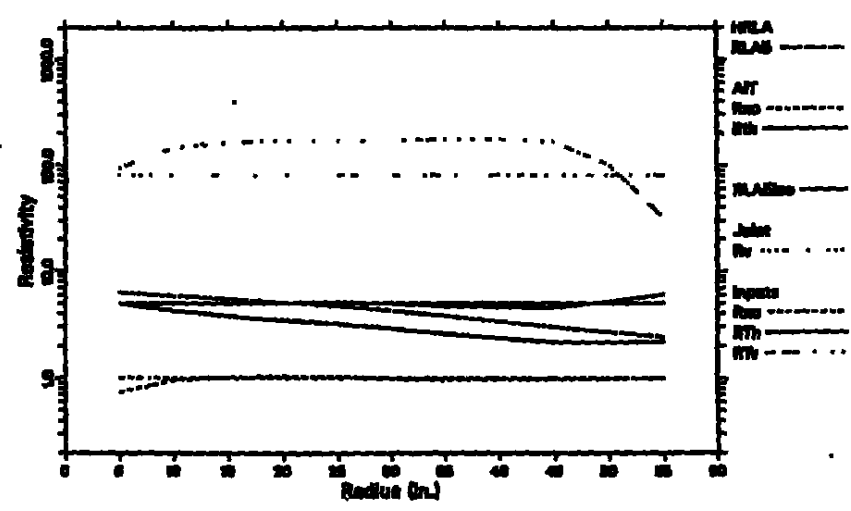
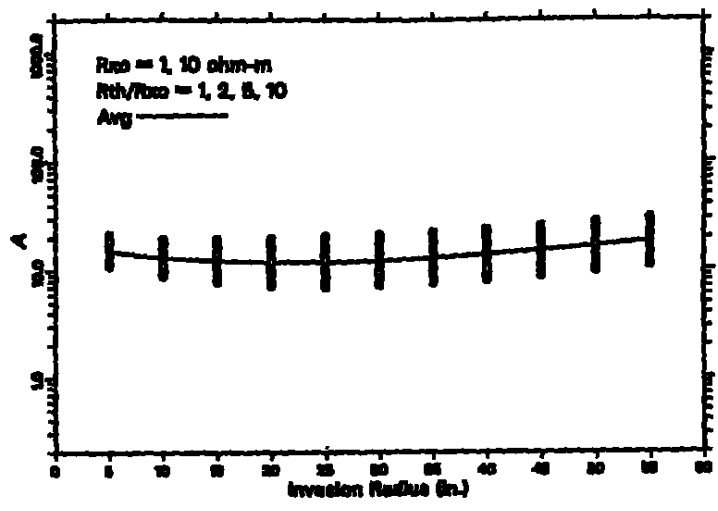


FIG. 11

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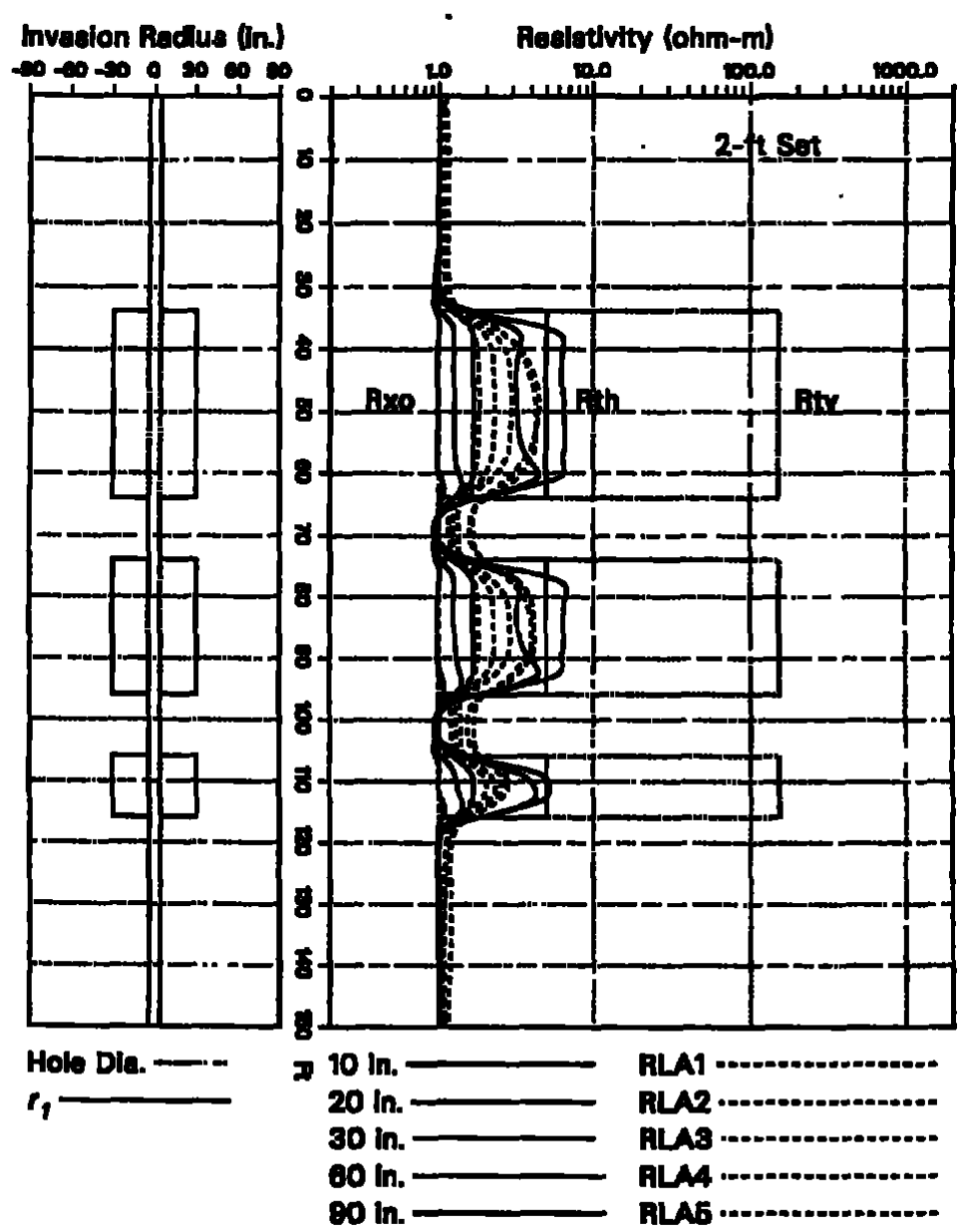


FIG. 14

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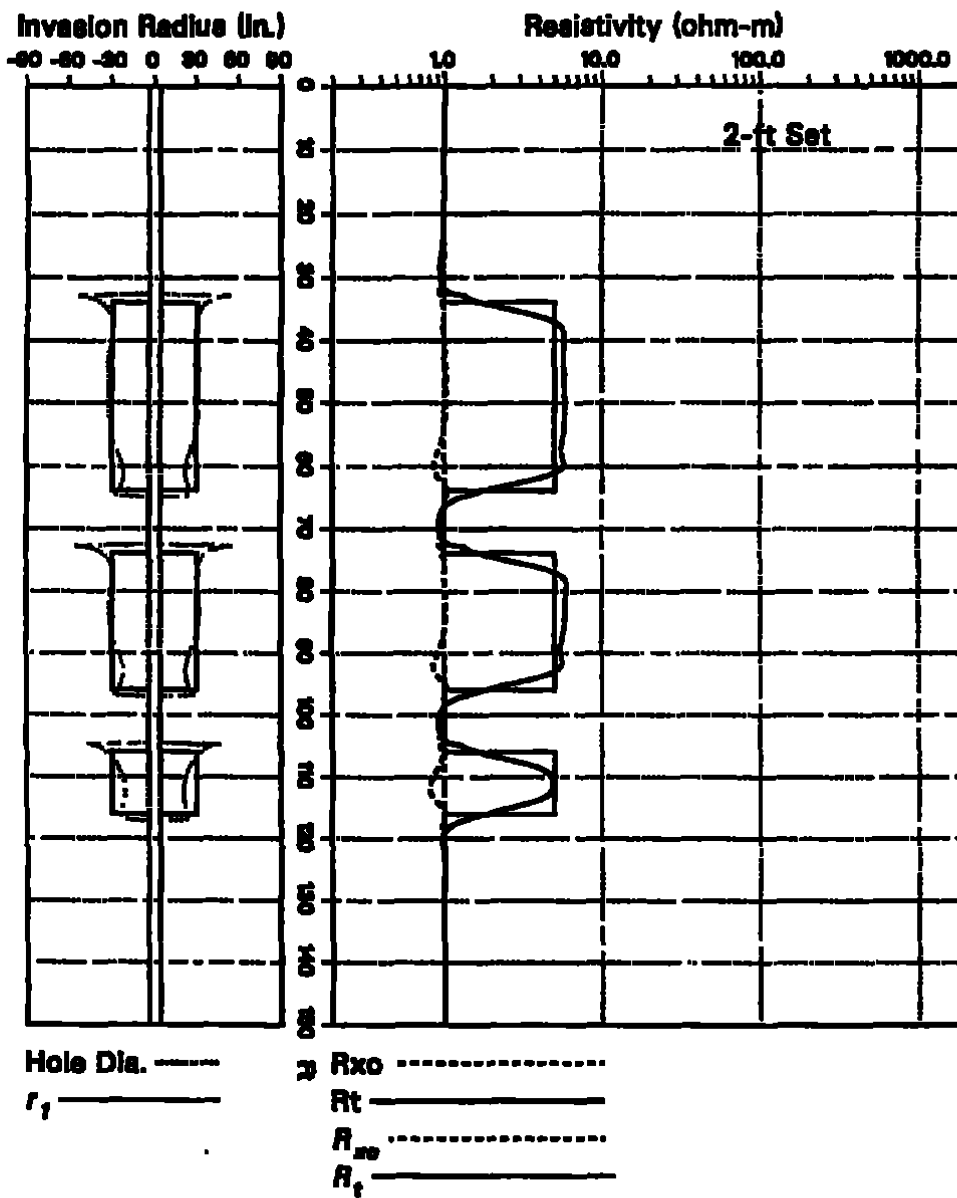


FIG. 15

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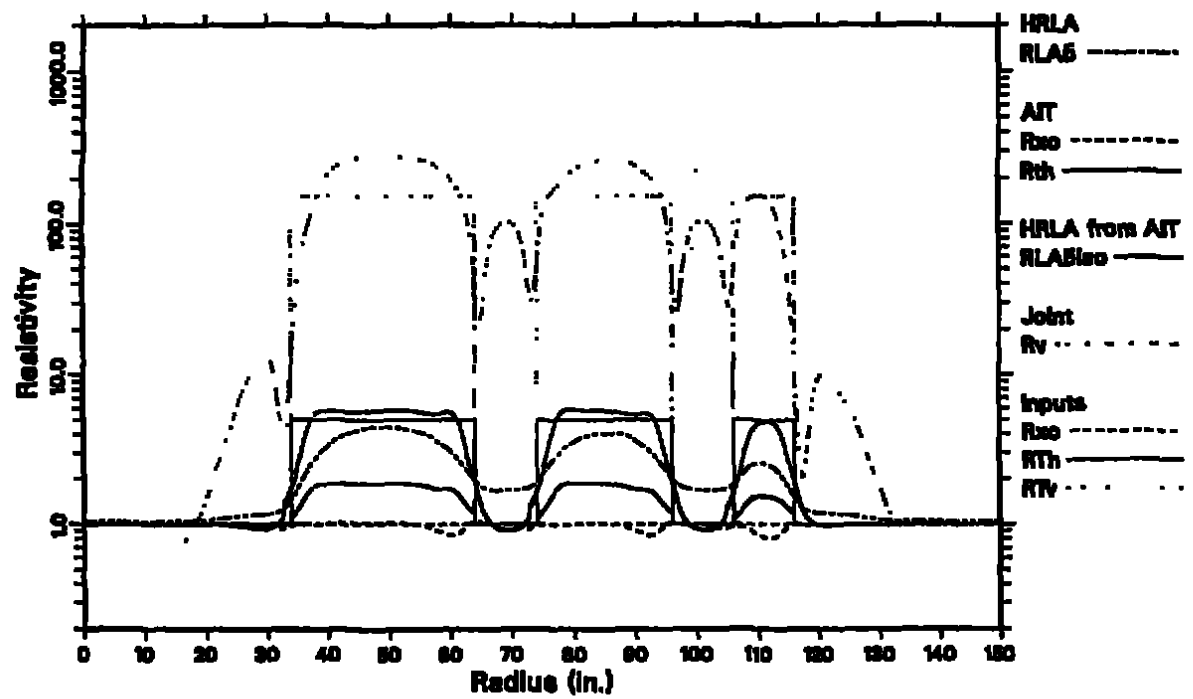


FIG. 16

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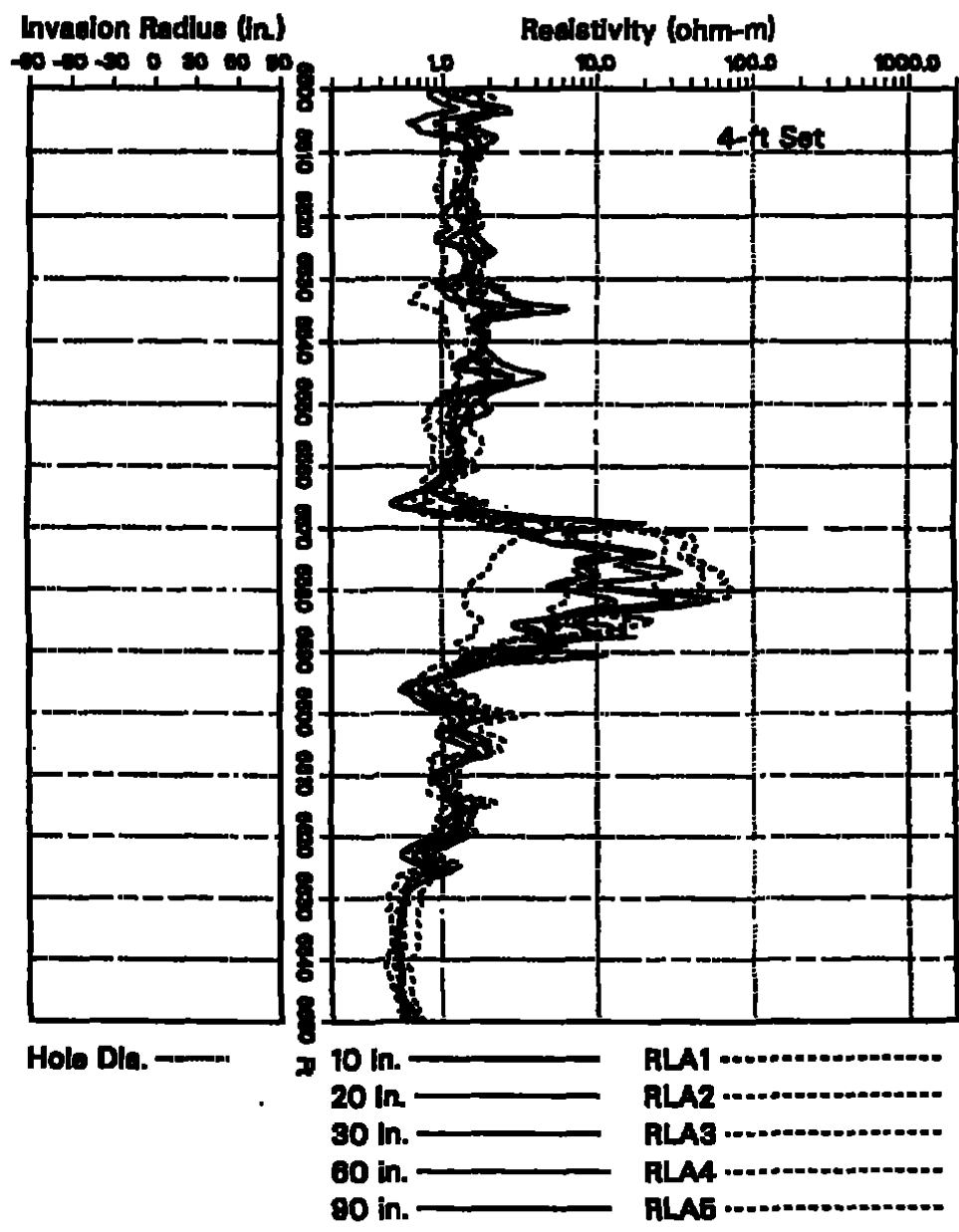


FIG. 17

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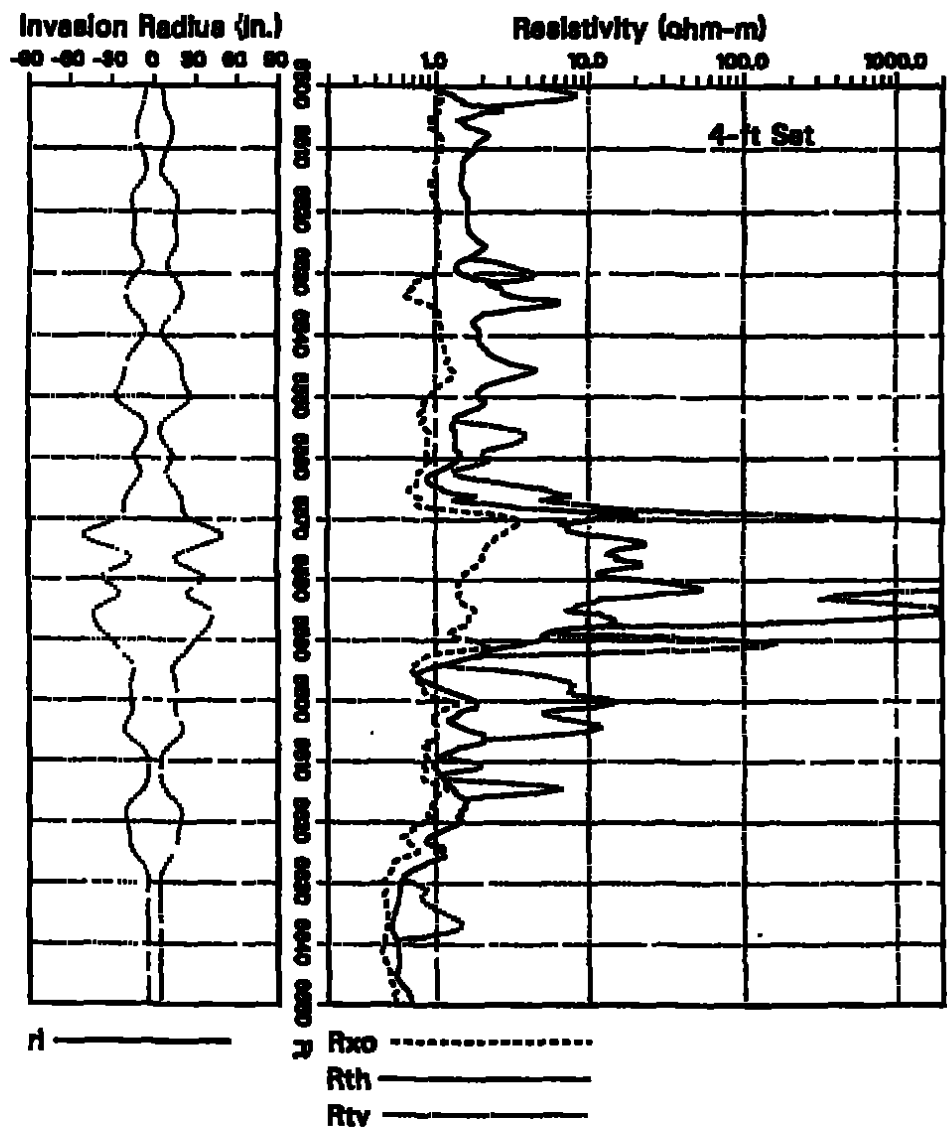


FIG. 18

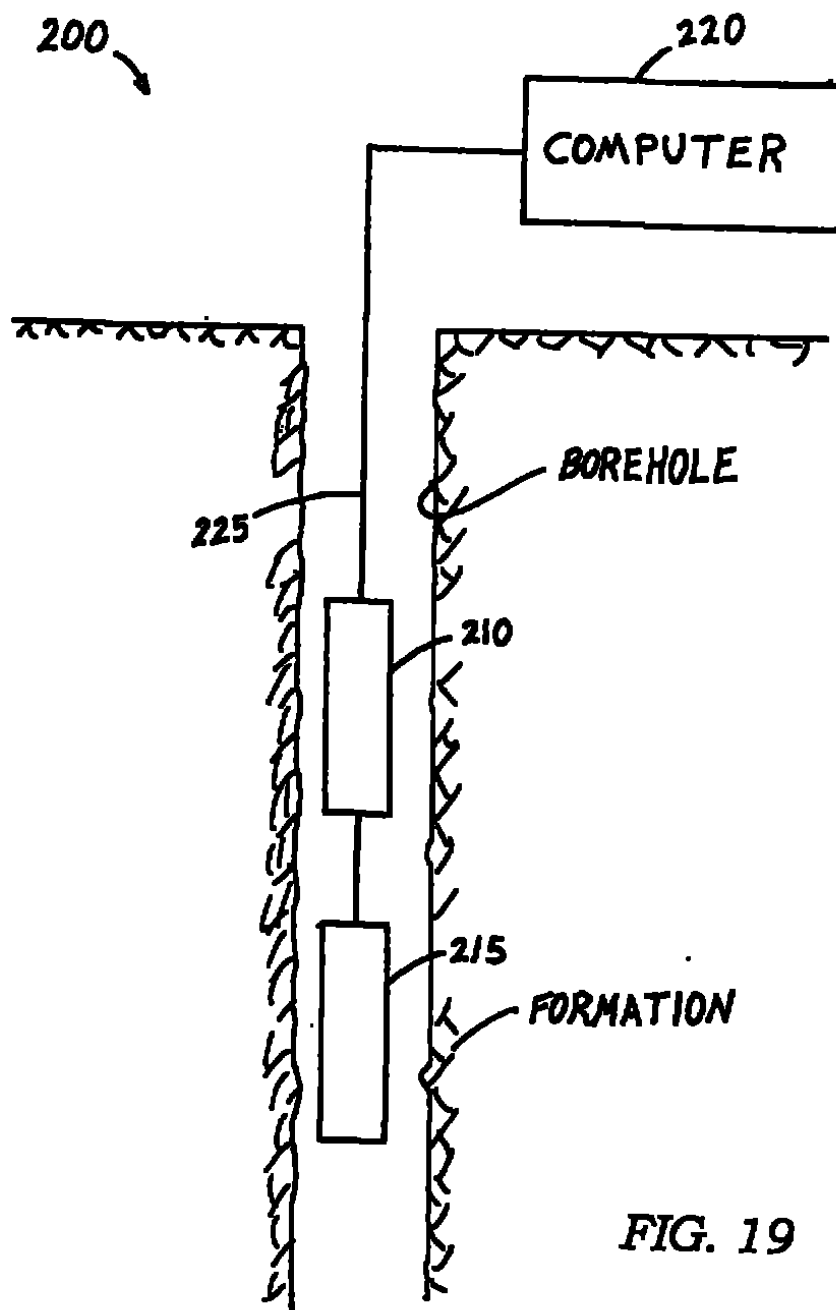


FIG. 19

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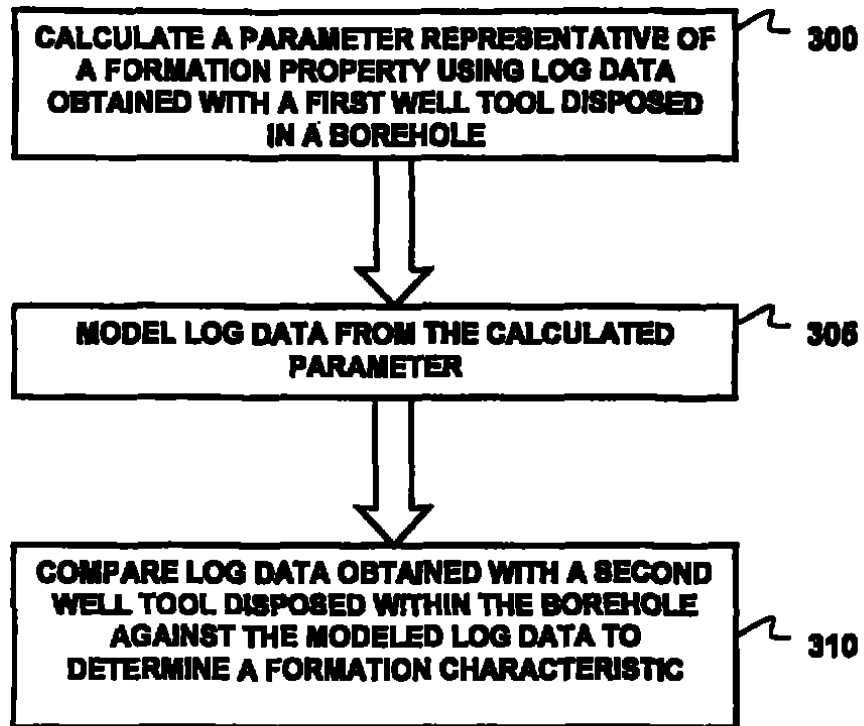


FIG. 20

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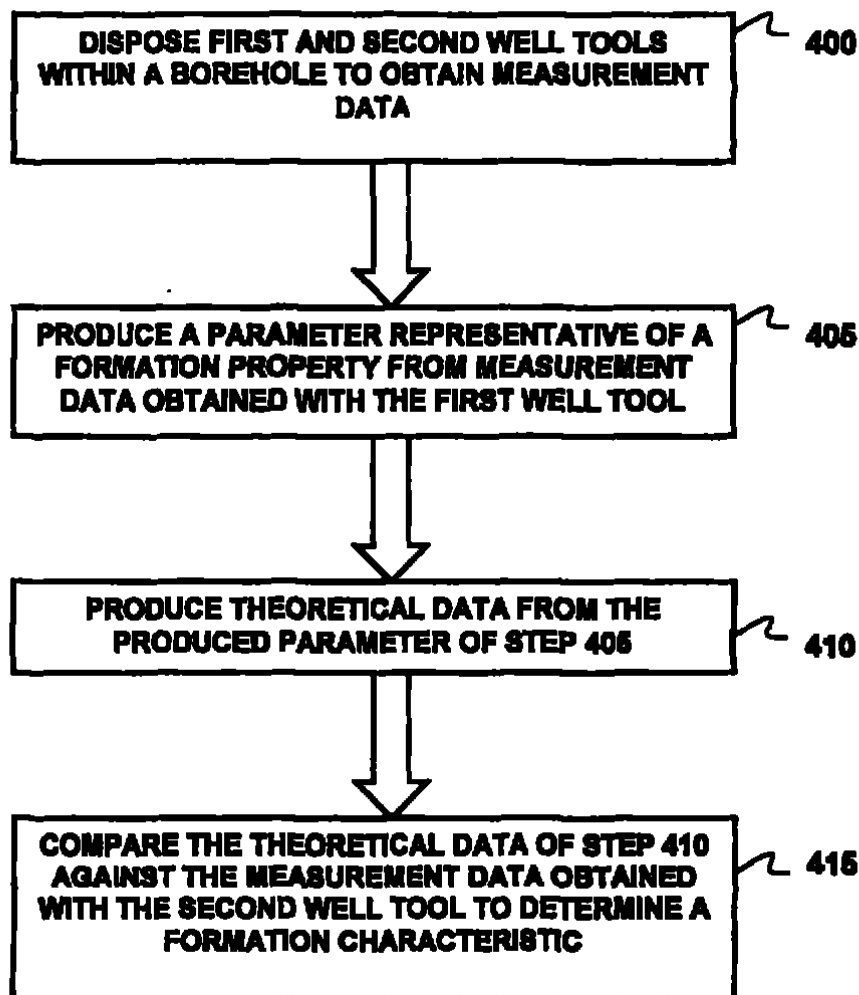


FIG. 21

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2do. EXAMEN DE FORMA PATENTE DE INVENCION

Folio 106

Radicación no 01-43631
Concepto Técnico no. 537
Clasificación Internacional de Patentes : G 01 V 3/28

Practicado el examen de acuerdo a lo establecido en el Art. 38 de la Decisión 486 se determinó que esta solicitud de Patente de Invención:

- | | |
|--|---|
| SI ☒ NO ☐ | Contiene un resumen de la invención (Art.26-e). |
| SI ☒ NO ☐ | Contiene el título o nombre de la invención (Art.27-d). |
| SI ☒ NO ☐ | Contiene la descripción de la invención (Art.26-b). |
| SI ☒ NO ☐ | NO ES APLICABLE ☐ Contiene los dibujos necesarios para comprender la invención (Art.26-d) |
| SI ☒ NO ☐ | Contiene una o más reivindicaciones. (Art.26-c). |
| SI ☐ NO ☐ | NO ES APLICABLE ☒ Han sido desarrollados los productos y/o procedimientos a partir de recursos genéticos o de sus productos derivados de los que cualquiera de los Países Miembros es país de origen. (Art. 26- h). |
| SI ☐ NO ☐ | NO ES APLICABLE ☒ Los productos y/o procedimientos han sido obtenidos o desarrollados a partir de los conocimientos tradicionales de las comunidades indígenas, afroamericanas, o locales de los países miembros, de acuerdo a lo establecido en la Decisión 391 y sus modificaciones y reglamentaciones vigentes.(Art.26-l). |
| SI ☐ NO ☒ | La invención se refiere a un producto relativo a un material biológico. (Art.26-j). |
| SI ☒ NO ☐ | La prioridad coincide con la materia reivindicada. |
| SI ☒ NO ☐ | CUMPLE LOS REQUISITOS TÉCNICOS |

OBSERVACIONES Y OTROS: SI ☒ NO ☐ ver hoja(s) anexa(s)

1. Anexa un nuevo juego de figuras , folios del 47 al 60
2. Adjunta arte final, folio 62.
3. Anexa copia certificada de la solicitud de patente con la cual reclama prioridad, folios del 66 al 105

EXAMINADOR TÉCNICO
202048

Bogotá D. C. Marzo 18 de 2003.

Carrera 13 No. 27-00 Piso 5 y 10
Conmutador: 334 12 21-2-3-4
Fax: 281 31 25 e-mail: info@sic.gov.co
Santa Fe de Bogotá D.C. - Colombia

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102

Folio 495

2020
Bogotá DC

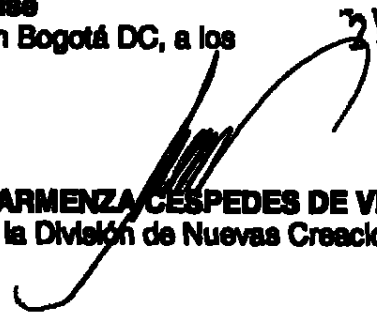
Doctor(a)
RAMIRO CASTRO DUQUE
Apoderado(a)

REFERENCIA:	Radicación No.	01-43631
	Trámite	002
	Evento	001
	Actuación	416
	Oficio No.	588
	Folios	001

Teniendo en cuenta que la solicitud de privilegio de patente que se tramita bajo el expediente indicado en la referencia, reúne los requisitos de forma establecidos en los artículos 26 y 27 de la Decisión 486 de la Comisión de la Comunidad Andina, y en las demás disposiciones vigentes sobre la materia, se envía el extracto de la solicitud a la Oficina de Comunicaciones para efecto de su publicación en la Gaceta de Propiedad Industrial, conforme lo establece el artículo 40 de la misma Decisión.

Cúmplase
Dado en Bogotá DC, a los

25 MAR 2009


ALIX CARMENZA CESPEDES DE VERGEL
Jefe de la División de Nuevas Creaciones

202048

DIVISION DE NUEVAS CREACIONES

RADICACIÓN EXPEDIENTE No 01-043631

EL EXTRACTO DE LA PRESENTE SOLICITUD DE PATENTE DE INVENCION

FUE PUBLICADO EN LA GACETA DE PROPIEDAD INDUSTRIAL No 530, DE

FECHA 31 DE JULIO DE 2003, EL TERMINO HABIL SEÑALADO POR LA LEY

EXPIRA EL 28 DE OCTUBRE DE 2003

NOTA: Dentro del plazo de los seis (6) meses siguientes a partir de la fecha de publicación en la gaceta de Propiedad Industrial, deberá solicitar y cancelar el examen de patentabilidad so pena de que la solicitud calga en abandono, de acuerdo con lo establecido en el Artículo 44 de la Decisión 486/2000.

SE PRESENTARON OPOSICIONES POR PARTE DE TERCEROS.

SI

NO **X**

Bogotá D.C, JUNIO DE 2005