DMEA Form 9

UNITED STATES
DEPARTMENT OF THE INTERIOR
Defense Minerals Exploration Administration

OFFICIAL DOCKET FILE

DMEA NO. 4610

Application (~~Denied~~
(Withdrawn ✓
(After disposition, delete items not applicable)

Contract (Terminated - not Certified
(Cancelled
(Terminated - Certified
(Royalty Agreement

This is the official contract file containing all official records of the project. The records contained in the files are checked and are arranged in this order:

Left Side

Interim Royalty Audits
Reports of Royalty Review
Certification of Discovery
Certificate of Audit (Final)
Interim Audit(s)
Report of Review
Termination Notice or Agreement
Recision Notice
Assignment of Contract
Contract Amendments (latest on top)
Contract with all exhibits and annexes
Owner's Consent to Lien
Subordination Agreement
✓ Leases and assignments of leases
✓ Application and attachments
(3) Envelope for maps

Right Side

Project summary
Work completed analysis
All other material is filed in chronological order with correspondence including the following reports as checked:

Final Field Team Report (Tab)
Operator's Final Report
(2R) Interim Reports
(2R) Operator's monthly reports and all attachments (latest on top)
On-site Exam Report(s) (Tab)
(4) Settlement Sheets

When the volume of records is expected to warrant additional folders, or when convenience of reference warrants separate folders for certain records, they should be set up in this order:

Left Side

Folder No. 2: (In chron. order)
Interim Summary Reports by W. O. Engineers

Right Side

Operator's Semi-Annual Report for Certified Project, Field Team Interim Reports, Operator's Monthly Report with transmittal, narrative, maps, and Field Team review.

Folder No. 3: Maps (Use pocket folder or envelope. Fold maps with title block out and show reference to related document or correspondence.)

Folder No. 4: Settlement Sheets

Folder No. 5: Drill Logs

RECEIVED
MINERALS TECHNOLOGY
DIVISION
JAN 21 1957
BUREAU OF MINES
JOPLIN, MO.

EXHIBIT "A"

RECEIVED
JAN 24 1957
DMEA

MINERAL LEASE

THIS AGREEMENT, made this the 24th day of September, 1956, between Fowlkes Brothers, a partnership composed of Edwin Fowlkes of Brewster County, Texas, and J. M. Fowlkes of Presidio County, Texas, and The Texas and Pacific Railway Company, a corporation created by and existing by virtue of Acts of Congress of the United States, with offices in Dallas, Texas, acting herein by and through its Vice-president and with the attestation of its Secretary and pursuant to a resolution made and passed by its Board of Directors authorizing this lease, as Lessor, (whether one or more) with Trans-Pecos Minerals, Inc. of Nueces County, Texas, with offices at Robstown, Nueces County, Texas, acting herein by and through its President and with the attestation of its Secretary and pursuant to a resolution made and passed by its Board of Directors authorizing this lease and agreement, as Lessee, witnesseth:

I.

Lessor does by these presents lease and demise unto Lessee the following described property, to-wit:

> Being six hundred and forty (640) acres of land in Presidio County, Texas, described as Section Seventy-one (71), Block G-5, Certificate 505, Abstract 3862, D & W Railway Survey, Presidio County, Texas;

Said lease upon the following term and conditions:

1. Lessee agrees to make a detailed geological study of the land within ninety (90) days and on or before the expiration of thirty (30) days thereafter file an appropriate application with the Department of Interior, Defense Minerals Exploration Administration, for government participation in the exploration of such tract and thereafter to conduct such exploration according to the schedules set forth in the Defense Minerals Ex-

ploration Administration contract; thereafter should there be approval of the tract for mining by Defense Minerals Exploration Administration, Lessee agrees within sixty (60) days after such approval to file with the Atomic Energy Commission an application for permission to mine ore from the premises. Upon receipt of approval from such authority to mine from Atomic Energy Commission and such other agencies of the United States Government as may be necessary to lawfully mine the premises, Lessee agrees to commence and continuously prosecute mining operations without interruption of more than ninety (90) days subject to the terms of Paragraph VII hereof.

2. Lessor hereby grants, leases and lets exclusively unto the Lessee the above described tract of land for the purpose of investigating, exploring, prospecting, drilling, mining, producing, storing, saving, treating, transporting, owning and selling all minerals in and under the premises.

3. Lessee shall have the right to build roads, power stations, telephone lines, laboratories, shafts, drifts or stopes and all other structures thereon or thereunder in order to produce and mine the minerals from the premises and shall have the further right to provide housing for its employees upon the premises.

4. This lease shall remain in force for a term of Ten (10) years from the date hereof and so long thereafter as ore, metals or non-metallic minerals shall be mined from said land in paying quantities, but shall be subject to forfeiture or termination at any time, as hereinafter provided, for the breach of any of the covenants hereof by Lessee. If ore, metals, or non-metallic minerals are not being mined from said land in paying quantities at the expiration date of the primary term, then this lease shall automatically terminate, and Lessee shall execute and deliver to Lessor a recordable release thereof.

5. It is specifically agreed between the parties hereto that this lease does not cover or include oil or gas.

E.F.
J.M.F.

II.

The royalties to be paid by the Lessee to the Lessor shall be on a sliding scale based upon a percentage of the net smelter returns per ton of ore so calculated as to include transportation costs from mine portal to the smelter. Said sliding scale is as follows:

$ 6.00 per ton or less	5 %
$ 7.00 to $ 10.00	6 %
$ 11.00 to $ 30.00	7 %
$ 31.00 to $ 50.00	10 %
$ 51.00 to $100.00	12½%
$101.00 to $200.00	15 %
$201.00 to $300.00 and over	20 %

This royalty scale shall not apply to oil, gas or uranium.

III.

Lessee shall have free use of water and coal, if any, from said land for all operations hereunder, however, Lessor makes no warranty or representation concerning the availability or sufficiency of any of said commodities.

IV.

Lessee agrees, during the primary period of this lease, to conduct a core-drilling program upon the premises taking such cores to hold depths horizontally, on inclines or perpendicularly to the surface as may be advisable and as determined by Lessee's consultants. Lessor shall at all times have access to the assays of such cores as well as the records and results of exploration or mining operations upon the premises.

Lessee, at its own expense and cost, agrees to maintain an insurance policy or policies in effect during the term of this lease indemnifying Lessors against any legal or lawful claim of the public against it with limits of Fifty Thousand and NO/100 Dollars ($50,000.00) and One Hundred Thousand and NO/100 Dollars ($100,000.00) as defined by current underwriting practices.

V.

During the primary period of this lease, Lessee may, at its option for experimental purposes mine and sell any ores from dumps or excavations from the premises, paying to Lessor royalties therefor upon the prices and percentages determined by the schedule set out in Paragraph II hereof.

VI.

Lessee shall have the right at any time during or within six (6) months after the expiration of this lease to remove all property and fixtures placed by Lessee upon said land.

VII.

Lessee agrees to mine the premises for hard minerals during the term of this lease, however, when mining operations are delayed or interrupted by storm, flood or other act of God, fire, explosion, rebellion, insurrection, riot, strikes, differences with workmen, economic unsoundness in mining operations in the judgment of Lessee, failure of carriers to transport or furnish facilities for transportation, or the result of some order, requisition or necessity of the government, or inability of Lessee to secure adequate workmen's compensation insurance coverage, or as a result of any cause whatsoever beyond the control of Lessee, the time of delay will not be counted against Lessee, anything in this lease to the contrary notwithstanding. All express or implied covenants of this lease shall be subject to all Federal and State laws, Executive orders, rules and regulations, and this lease shall not be terminated, in whole or in part, nor Lessee be held liable in damages for failure to comply therewith, if failure is the result of, or compliance is prevented by any such law, order, rule or regulation, and during the primary term hereof the Lessee shall pay as a rental for delay in any operation hereunder the sum of Two Dollars ($2.00) per acre per year to the Lessors, as their interest may appear.

VIII.

Lessee may, at its option, mine and sell any uranium ores including deposits of minerals from which thorium, uranium, titanium and radioactive elements or their isotopes higher than uranium in the periodic table can be refined or produced, as well as all deposits from which there can be refined or produced other substances capable of the production of nuclear fission, or the release of atomic energy, and to pay to Lessor therefor the following sliding scale royalties determined by the assays of the ores of U_3O_8 or like oxides of radioactive elements to-wit:

Less than		.3 %	5 %
.3	to	.35%	5½%
.35	to	.45%	6½%
.45	to	.55%	7½%
.55	to	.65%	8½%
.65	to	.75%	9½%
.75	to	.85%	10½%
.85	to	.95%	11½%
.95	to	1.50%	12½%
1.50	to	2.50%	13½%
2.50	to	3.50%	14½%
3.50	to	4.50%	15½%
4.50	to	5.50%	16½%
5.50	to	6.50%	17½%
6.50	to	7.50%	18½%
7.50	to	8.50%	19½%
8.50	to	9.50%	20½%
9.50	and over		21 %

Lessor shall be paid the foregoing applicable royalty percentages of the field market price at the mine, excluding allowances for transportation and development, bonus payments and premiums, as paid by the Atomic Energy Commission or other government authorized agency or mill; but in no event shall Lessee be required to establish or to petition of the Atomic Energy Commission or any representative thereof or any political agency of the government, a buying station, custom milling contract or other government agency designed arrangement for storing or stock-piling such crude ores. Lessee agrees to report all such discoveries of radioactive substances to Lessor and Lessor may, in the event Lessee declines this option, mine and market same provided such operation does not interfere with Lessee's established mining operations.

IX.

If said Lessor owns a less interest in the above described land than the entire and undivided fee simple estate or no interest therein, then the royalties herein provided for shall be paid the said Lessor only in proportion which Lessor's interest, if any, bears to the whole and undivided fee.

X.

If the estate of either party hereto is assigned (and the privilege of assigning in whole or in part is expressly allowed) the covenants hereof shall extend to their heirs, executors, administrators, successors, or assigns, but no change in the ownership of the land or assignment of royalties shall be binding on the Lessee until after the Lessee has been furnished with a written transfer or assignment, or a certified copy thereof; and it is hereby agreed that in the event this lease shall be assigned as to a part or as to parts of the above described lands and assignee or assignees of such part or parts shall fail or make default in the payment of the proportionate part of the royalties due from him or them, such default shall not operate to defeat or affect this lease so far as it covers a part or parts of said land upon which the said Lessee or any assignees thereof shall make due payment of said royalties.

XI.

In the event Lessor considers that Lessee has not complied with all its obligations hereunder, both express and implied, before production has been secured or after production has been secured, Lessor shall notify Lessee in writing, setting out specifically in what respects Lessee has breached this contract. Lessee shall then have sixty (60) days after receipt of said notice within which to meet or commence to meet all or any part of the breaches alleged by Lessor. The service of said notice shall be precedent to the bringing of any action by Lessor

on said lease for any cause, and no such action shall be brought until the lapse of sixty (60) days after service of such notice on Lessee. Neither the service of said notice nor the doing of any acts by Lessee aimed to meet all or any of the alleged breaches shall be deemed an admission or presumption that Lessee has failed to perform all its obligations hereunder.

XII.

Lessee shall have the right at any time to redeem for Lessor by payment any mortgages, taxes or other liens or interest and other charges on the above described lands in the event of default of payment by Lessor and be subrogated to the rights of the holder thereof and to deduct amounts so paid from royalties or other payments due or which may become due under this lease.

XIII.

In order to reduce transportation costs of ores shipped from this property, Lessee may, at its option, develop concentrates on or off location or by contract therefor and in so doing charge the actual cost per ton of concentration to the operation of transportation from mine portal to smelter and the royalty payments specified in Paragraph II hereof shall be thereupon determined after deduction of the concentration and transportation charges.

XIV.

Lessor agrees to execute such subordination or consent to lien agreement in favor of the United States of America as may be required by the Department of Interior, Defense Minerals Exploration Administration in the course of a joint exploration by such agency and Lessee or its assigns.

In Witness Whereof, the parties hereto have caused these presents to be executed as shown below by the respective officers acting in their duly authorized capacity as officers

of the named corporations and on behalf of said corporations.

FOWLKES BROTHERS

By _____ and

By _____
Partners.

THE TEXAS AND PACIFIC RAILWAY COMPANY

By _____
Vice-President

ATTEST:

_____

TRANS-PECOS MINERALS, INC.

By _____
President

_____

THE STATE OF TEXAS, |
COUNTY OF ~~BREWSTER~~ Presidio. |

BEFORE ME, THE UNDERSIGNED AUTHORITY, on this day personally appeared Edwin Fowlkes, known to me to be the person

whose name is subscribed to the foregoing instrument, and acknowledged to me that he executed the same for the purposes and consideration therein expressed and in the capacity therein stated.

GIVEN UNDER MY HAND AND SEAL OF OFFICE, This the 28 day of ~~September,~~ December 1956.

Norman C. Davis, Notary Public
In and for Presidio County, Texas

NOTARY PUBLIC, ~~BREWSTER~~ Presidio COUNTY, TEXAS.

THE STATE OF TEXAS, |
COUNTY OF PRESIDIO. |

BEFORE ME, THE UNDERSIGNED AUTHORITY, on this day personally appeared J. M. Fowlkes, known to me to be the person whose name is subscribed to the foregoing instrument, and acknowledged to me that he executed the same for the purposes and consideration therein expressed and in the capacity therein stated.

GIVEN UNDER MY HAND AND SEAL OF OFFICE, This the 31 day of ~~September,~~ December 1956.

Norman C. Davis, Notary Public
In and for Presidio County, Texas

NOTARY PUBLIC, PRESIDIO COUNTY, TEXAS.

THE STATE OF TEXAS, |
COUNTY OF DALLAS. |

BEFORE ME, THE UNDERSIGNED AUTHORITY, on this day personally appeared J. J. Finegan, Vice-president, known to me to be the person and officer whose name is subscribed to the foregoing instrument and acknowledged to me that the same was the act of the said Texas and Pacific Railway Company, a corporation and that he executed the same as the act of such corporation for the purposes and consideration therein expressed, and in the capacity therein stated.

GIVEN UNDER MY HAND AND SEAL OF OFFICE, This the 18 day of ~~September~~ December, 1956.

Gladys Arnold
Gladys Arnold
NOTARY PUBLIC, DALLAS COUNTY, TEXAS.

THE STATE OF TEXAS, }
COUNTY OF NUECES. }

BEFORE ME, THE UNDERSIGNED AUTHORITY, on this day personally appeared Herman G. Wood, President, known to me to be the person and officer whose name is subscribed to the foregoing instrument and acknowledged to me that the same was the act of the said Trans-Pecos Minerals, Inc., a corporation and that he executed the same as the act of such corporation for the purposes and consideration therein expressed, and in the capacity therein stated.

GIVEN UNDER MY HAND AND SEAL OF OFFICE, This the 25 day of September, 1956.

H J Epps
NOTARY PUBLIC, NUECES COUNTY, TEXAS.
H.J. Epps

NOTARY PUBLIC COUNTY OF NUECES, TEXAS

APPROVED AS TO FORM
ATTORNEY

APPROVED AS TO PROPERTY INTERESTS
DIRECTOR OF INDUSTRIAL DEVELOPMENT

THE STATE OF TEXAS }
COUNTY OF PRESIDIO } I, DELLA BOND, County Clerk in and for said County, do hereby certify that the foregoing instrument of writing with its certificate of authentication was filed for record in my office on the 2 day of Jan. A. D., 1957 at 11:45 o'clock A.M. and duly recorded the 3 day of Jan. A. D., 1957 at 10:45 o'clock A.M., in the Deed Records of said County, in Vol. 147 on page 169-174.

WITNESS my hand and the seal of office, at my office in Marfa, Texas.

By: _____ Deputy

Della Bond
County Clerk, Presidio County, Texas

COMPARED INDEXED

FILED FOR RECORD

Jan. the 2 1956 at 11:45 o'clock A.M.

Della Bond

County Clerk, Presidio County, Texas

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION
~~WASHINGTON 25, D. C.~~
Box 431
Joplin, Missouri

OFFICIAL FILE COPY
DMEA
RECEIVED JAN 24 1957

DATE	INITIALS	CODE

January 22, 1957

D.M.E.A. Operating Committee
Department of the Interior
Washington 25, D. C.

Re: Uranium-mercury Application
to be filed for DMEA assistance
on Section 71, Block G-5,
Presidio County, Texas

Dear Sirs:

Forwarded herewith is the original of the subject application as received today from Trans-Pecos Minerals, Inc., Box 191, Robstown, Texas. Forwarded under separate cover for eventual use there by the reviewers in the Geological Survey and Bureau of Mines are two copies of the application(excepting the photocopies retained here of the lengthy Geological Survey report - "Exhibit D" - which seems to have little direct bearing on the section 71 prospects, and which I believe is an open file available to you in Washington as it was to the Applicant in the Office of the State Geologist of Texas). These other two copies of "Exhibit D" will be mailed, however, if you so request. The fourth copy of the application also is being retained for eventual Field Team review. The Section 71 prospects are 3½ miles northwest of the Fresno (Smith & Wilson) mercury mine(Docket DMA-2202X).

The Applicant indicates that as soon as sample results, maps, and other technologic data on the prospecting becomes available, the necessary geologic justification, detailed plans, and cost estimates for the proposed explorations will be evidenced in an amendment to this Application.

Pending receipt of all the essentials required in the Application, I suggest that processing in Washington be held in abeyance.

Sincerely yours,

Clinton C. Knox

Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV

Encl.

cc: Mr. Roger Butler,Robston,Tex.
DMEA Op.Com.(2)w/c of appl.
Mr. King,USGS,Denver
Appl.Pend.File

Roger Crit Butler

January 19, 1957

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DMEA
RECEIVED JAN 24 1957

DATE	INITIALS	CODE

Mr. Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV
Box 431
Joplin, Missouri

Dear Mr. Knox:

I enclose four copies of the application of Trans-Pecos Minerals, Inc. for a DMEA exploration project contract in connection with Section 71, Block G-5, D & W Railway Survey, Presidio County, Texas.

I will appreciate the opportunity to supplement this application. This filing complies with the provisions of our contract as shown by Exhibit "A", sub-paragraph number 1 of paragraph 1.

No subordination agreement is included in this application as Exhibit "A", paragraph fourteen provides for such subordination or consent to lien.

Yours very truly,

/s/Roger Butler
/t/Roger Butler

RB:ogs

MF-103
(Revised April 1952)

UNITED STATES DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION

Form Approved.
Budget Bureau No. 42-R1035.2.

APPLICATION FOR AID IN AN EXPLORATION PROJECT, PURSUANT TO DMEA ORDER 1, UNDER THE DEFENSE PRODUCTION ACT OF 1950, AS AMENDED

RECEIVED
MINERALS TECHNOLOGY DIVISION
JAN 21 1957
BUREAU OF MINES
JOPLIN, MO.

RECEIVED
JAN 24 1957
D.M.E.A.

Not to be filled in by applicant

Docket No. 4610
Metal or Mineral Uranium - Mercury
Date Received 1-24-57
Estimated Cost $74,280
Participation (Government %)

INSTRUCTIONS

1. *Name of applicant.*—(*a*) State here your full legal name, in the form in which you will wish to contract, and your mailing address: Trans-Pecos Minerals, Inc., Post Office Box 191, Redstown, Texas.

(*b*) If other than an individual, add to your name above whether a corporation, partnership, etc., and the name of the State in which incorporated or otherwise organized.

(*c*) If a corporation, add to above statement, titles, names and addresses of officers.

(*d*) If a partnership, add to the above statement the names and addresses of all partners.

2. *General.*—Read DMEA Order 1, "Government Aid in Defense Exploration Projects," before completing this application. Submit this application and all accompanying papers in quadruplicate (four copies), with your name and address on each sheet of the application and on all accompanying papers. Where sufficient space is not provided on the form for all required information, state it on an accompanying paper, with a reference in each case to the instruction to which it refers by number. Comply with all applicable instructions; or, if not applicable, so state. File the application with Defense Minerals Exploration Administration, Department of the Interior, Washington 25, D. C., or with the nearest field executive officer thereof.

3. *Applicant's property rights.*—(*a*) State the legal description of the land upon which you wish to explore, including all land which you possess or control that may be benefited by the exploration, and excluding any land or interest in land which is not to be included in the exploration project contract Six Hundred and Forty (640) acres of land in Presidio County, Texas, described as Section Seventy-ONE (71), Block G-5, Certificate 505, Abstract 3862, D & W Railway Survey, Presidio County, Texas.

(*b*) State any mine name by which the property is known.

(*c*) State your interest in the land, whether owner, lessee, purchaser under contract, or otherwise Lessee

(*d*) If you are not the owner, submit with this application a copy of the lease, contract, or other document under which you control the property.

(*e*) If you own the land, describe any liens or encumbrances on it Not applicable.

(*f*) If the land consists of unpatented claims, add to the description above, the book and page numbers for each recorded location notice.

4. *Physical description.*—(*a*) Describe in detail any mining or exploration operations which have been or now are being conducted upon the land, including existing mine workings and production facilities. State your interest, if any, in such operations. Also describe accessibility of mine workings for examination purposes.

(*b*) State past and current production, and ore reserves, if any, giving quantities and grades.

(*c*) Describe the geologic features of the property, including mineralization, type of deposit (vein, bedded, etc.), and your reasons for wishing to explore. Illustrate with maps or sketches. Send with your application (but not necessarily as a part of it) any geologic or engineering report, assay maps, or other technologic information you may have, indicating on each whether you require its return to you.

(*d*) State the facts with respect to the accessibility of the project: Access roads, distances to shipping, supply and residence points.

(*e*) State the availability of manpower, materials, supplies, equipment, water, and power.

16—66551-1

5. *The exploration project.*—(*a*) State the mineral or minerals for which you wish to explore uranium, vanadium and cinnabar

(*b*) Describe fully the proposed work, including a map or sketch of the property showing a plan (and cross sections if needed) of any present mine workings, and the location of the proposed exploration work as related to such features as contacts, veins, ore-bearing beds, etc.

(*c*) The work will start within 30 days and be completed within 100 days from the date of an exploration project contract.

(*d*) State the operating experience and background of the applicant with relation to the ability to carry out such exploration project, and also that of the person or persons who will supervise the operations.

6. *Estimate of costs.*—Furnish a detailed estimate of the costs of the proposed work (you will have to use a separate sheet), under the following headings. Add the totals under all headings to give the estimated total cost of the project:

(*a*) *Independent contracts.*—(Note.—If the applicant does not intend to let any of the work to contractors, write "none" after this item. To the extent that the work is to be contracted, do not repeat the cost of the contract-work in subsequent items.) State the cost of any proposed independent contracts for the performance of all or any part of the work, expressed in terms of units of work (such as per foot of drilling, per foot of drifting, per hour of bulldozer operations, per cubic yard of material moved, etc.).

(*b*) *Labor, supervision, consultants.*—Include an itemized schedule of numbers, classes and rates of wages, salaries or fees for necessary labor, supervision and engineering and geological consultants.

(*c*) *Operating materials and supplies.*—Furnish an itemized list, including items of equipment costing less than $50 each, and power, water and fuel.

(*d*) *Operating equipment.*—Furnish an itemized list of any operating equipment to be rented, purchased, or which is owned and will be furnished by the Operator, with the estimated rental, purchase price, or suggested use-allowance based on present value, as the case may be.

(*e*) *Rehabilitation and repairs.*—Furnish a detailed list showing the cost of any necessary initial rehabilitation or repairs of existing buildings, installations, fixtures, and movable operating equipment, now owned by the Operator and which will be devoted to the exploration project.

(*f*) *New buildings, improvements, installations.*—Furnish a detailed list showing the cost of any necessary buildings, fixed improvements, or installations to be purchased, installed or constructed for the benefit of the exploration project.

(*g*) *Miscellaneous.*—Furnish a detailed list showing the cost of repairs to and maintenance of operating equipment (not including initial rehabilitation or repairs of the Operator's equipment), analytical work, accounting, workmen's compensation and employers' liability insurance, and payroll taxes.

(*h*) *Contingencies.*—Give an estimate of any necessary allowances for contingencies not included in the costs stated above.

NOTE.—No items of general overhead, corporate management, interest, taxes (other than payroll and sales taxes), or any other indirect costs, or work performed or costs incurred before the date of the contract, should be included in the estimate of costs.

7. (*a*) Are you prepared to furnish your share of the cost of the proposed project in accordance with the regulations on Government participation (Sec. 7, DMEA No. 1)?

(*b*) How do you propose to furnish your share of the costs?

[X] Money [ ] Use of equipment owned by you [ ] Other

Explain in detail on acompanying paper.

CERTIFICATION

The undersigned, whether as an individual, corporate officer, partner, or otherwise, both in his own behalf and acting for the applicant, certifies that the information set forth in this form and accompanying papers is correct and complete, to the best of his knowledge and belief.

Dated January 19, 1957

TRANS-PECOS MINERALS, INC.
(Applicant)

By Roger Butler
ROGER BUTLER, Vice-president

ATTEST:

Zilla Elliff
ZILLA ELLIFF, Secretary.

Title 18, U. S. Code (Crimes), Section 1001, makes it a criminal offense to make a willfully false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

U. S. GOVERNMENT PRINTING OFFICE 16—66551-1

RECEIVED
MINERALS TECHNOLOGY
DIVISION
JAN 21 1957
BUREAU OF MINES
JOPLIN, MO.

APPLICATION FOR AID IN AN EXPLORATION PROJECT

PURSUANT TO DMEA ORDER 1, UNDER THE

DEFENSE PRODUCTION ACT OF 1950

AS AMENDED.

OFFICIAL FILE COPY
D M E A
RECEIVED JAN 24 1957

DATE	INITIALS	CODE

TO: UNITED STATES DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION.

ITEM 1. (a) Trans-Pecos Minerals, Inc., Post Office Box 191, Robstown, Texas.

(b) Trans-Pecos Minerals, Inc. is a Texas corporation of Nueces County, Texas, with offices and principal place of business at Robstown, Texas.

(c) The names and addresses and titles of the corporation officers are:

Herman G. Wood, Post Office Box 191, Robstown, Texas, President.

Roger Butler, Post Office Box 71, Robstown, Texas, Vice-president.

Era H. Wood, 307 Ligustrum Boulevard, Robstown, Texas, Director.

Zilla Elliff, Post Office Box 191, Robstown, Texas, Secretary-Treasurer.

(d) Not applicable.

ITEM 2. Complied with by reading DMEA Order Number 1.

ITEM 3. Six Hundred and Forty (640) acres of land in Presidio County, Texas, described as Section Seventy-One (71), Block G-5, Certificate 505, Abstract 3862, D & W Railway Survey, Presidio County, Texas.

Lessee controls Section Sixty (60) and Sixty-two (62), containing twelve hundred and eighty (1280) acres of land in Presidio County, Texas, Block G-5, Certificate 505, Abstract 3862, D & W Railway Survey, Presidio County, Texas, by permission of the State of Texas, for a period of one (1) year from date August 10, 1956. This land may be benefited remotely by this application but it is the opinion of the company that the Texas method of leasing public lands is an unsatisfactory one where the minerals involved are uranium, vanadium and cinnabar.

(b) The prospect is not named but has been referred to by the Section number.

(c) Lessee.

(d) See Exhibit "A" attached.

(e) Not applicable.

(f) This land is owned in fee by Fowlkes Bros., a partnership and the Texas and Pacific Railway Company. Lessee applicant's lease is of record in Volume 147 on Page 169-174, of the Deed Records of Presidio County, Texas.

ITEM 4. (Attached is Exhibit "B"). The aerial photographic map of the area is described in Exhibit "C", a letter from a geologist, Carl R. Chelf, to Mr. Herman Wood of Trans-Pecos Minerals, Inc.

(a) No mining operations are now being conducted upon the land. No active exploration operations are now being conducted upon the land, however, geologic studies are being conducted and have been completed as a preliminary to the presentation of this application.

The records and evidence of exploratory operations which have been conducted, i.e. trenching and scintilation are accessible on location.

(b) None.

(c) The geologic features of the property are best described in the unpublished report of George A. Thompson, Jr. in the study entitled

Copy is in Division file case very poor photostat

"Structural Geology of the Terlingual Quicksilver District, Texas", attached here as Exhibit "D". The topographic maps attached as Exhibit "E" support the aerial photographic map. Exhibit "F" shows the relation of the carnotite to the boundaries of the tract.

The reasons for the exploration are:

(a) The location of a thickly bedded deposit i.e. in excess of seven (7) feet of carnotite and vanadium oxide in rather wide spread occurrence upon Section 71.

(d) The prospect lies three and one-half (3 1/2) miles North Northwest of the Smith mine as shown on Exhibit "B", an aerial photograph of the Solitario area. The prospect is accessible from Alpine, Texas, thence to Study Butte, thence to La Jitas, thence to the Smith mine and along the La Jitas - Marfa Stagecoach road, a total distance from Alpine, Texas, of one hundred and thirty-one (131) miles along the route described. The prospect is fifty-four (54) miles from a railway terminal at Presidio, Texas.

(e) Man power is available as skilled, semi-skilled, and ordinary labor from Alpine to Presidio to Marfa, Texas. Materials are available through mining supply houses at El Paso, Texas. Supplies are available through Alpine and El Paso, Texas. Equipment is available through El Paso, Texas. Water for diamond core drilling and mining is available within two (2) miles from the location. Electrical power is available at Terlingua, Texas or portable power is available at the prospect.

ITEM 5. (a) Uranium and Mercury.

(b) See Exhibit "C". Trans-Pecos Minerals, Inc. proposes to explore Section 71 and its reasons are summed up in the report of Mr. Carl R. Chelf, attached here as Exhibit "C". The thickness

of the bedded deposits and the wide spread occurrence of uranium, vanadium and cinnabar make the exploration program of extreme interest.

The applicant proposes a two (2) stage exploration program. The first stage is as follows:

> One hundred (100) hand augered holes, sixteen (16) feet deep at a cost of Five and 80/100 Dollars ($5.80) per foot, a total of Nine Thousand, Two Hundred and Eighty Dollars ($9,280.00). Removal of one hundred thousand (100,000) cubic yards of over burden averaging one and one-half (1 1/2) feet to one and three-fourth (1 3/4) feet in thickness by bulldozer at a price of Fifteen Cents (15¢) per cubic yard, a total of Fifteen Thousand Dollars ($15,000.00).
>
> Total estimated cost for stage 1 is Twenty-four Thousand, Two Hundred and Eighty Dollars ($24,280.00).

Stage 2 will depend upon whether or not the first stage should turn out to be encouraging and if it is, stage 2 will consist of the use of conventional and approved exploration technics and haulage of test samples to the Blue Water Mill in Grants, Mexico. The estimated cost of stage 2 will be Fifty Thousand Dollars ($50,000.00).

(c) The work will start within thirty (30) days and be completed within one hundred (100) days from the date of an exploration project contract.

(d) Trans-Pecos Minerals, Inc. is a Texas corporation organized for the purpose of conducting mining operations in Texas on January 17, 1956. Herman G. Wood is Executive Manager, has had ten (10) years practice experience in building and construction and nine (9) years in practice experience in lumber production and two (2) years experience in conducting mining exploration and

diamond core drilling operations. Mr. Carl R. Chelf, the company's geologist has had twenty (20) years experience in field geology and has personally supervised core drilling operations. Mr. Glenn Evans is employed as consulting geologist and has no direct connection with the company. He is a graduate of the University of Texas and has within the past years been associated with the Bureau of Economic Geology of the University of Texas and is now in the private practice of geology. Mr. Wood and Mr. Chelf will personally supervise the taking of each core and the stripping procedures.

ITEM 6. The estimate of cost is included in subdivision B of Item 5. The total actual work and materials being as follows:

Stage 1. $24,280.00 (excluding professional fees)
Stage 2. $50,000.00 (excluding professional fees)

(a) It is proposed that the company do the work on an actual cost basis in this way should the project not develop favorably from an exploration stand point a saving would be effected to the applicant and to the government.

(b) The cost of geologic consultation during the period of this contract will be Four Hundred Dollars ($400.00) per month for a period of four (4) months which would include eight (8) hours per day for eight (8) days per month. The cost of geologic supervision of the stripping and core taking will be Eight Hundred Dollars ($800.00) per month for a period of four (4) months which would include eight (8) hours per day for twenty (20) days per month.

(c) All operating materials and supplies will be furnished by the applicant and will consist of a hand auger, a four (4) man trenching crew, a two (2) man augering crew who will be paid a minimum of One Dollar ($1.00) per hour. The owner will furnish a bulldozer for the job, as well as all field supplies for this machine.

(d) The usual charge for the rental of a bulldozer with an operator furnished is One Hundred Dollars ($100.00) per day. Accordingly, it is submitted that the applicant will furnish such a machine at a comparable rate.

(e) No rehabilitation and repair is contemplated in this project.

(f) No new buildings or improvements are contemplated in this project.

(g) The applicant will furnish its own accounting and analytical work and employers' liability insurance. The applicant will furnish its own workmen's compensation and payroll taxes.

(h) No allowance is made for contingencies.

ITEM 7. (a) Yes.

(b) Money.

DATED this the 19th day of January, 1957.

N.B. Applicant here requests leave to amend this application upon completion of A. E. C. inspection, which inspection was originally scheduled for January 22, 1957, but due to the unavailability of applicant's geologist was cancelled.

N.B. 2 Exhibit "G" is attached as a general reference to the area and for the purpose of further identifying the prospect.

TRANS-PECOS MINERALS, INC.

By Roger Butler
ROGER BUTLER, Vice-president.

ATTEST:

Zilla Elliff
ZILLA ELLIFF, Secretary.

EXHIBIT "C"

AEC
RECEIVED JAN 24 1957

DATE	INITIALS	CODE

CARL R. CHELF
Box 918
Austin, Texas

January 13, 1957

RECEIVED
MINERALS DEPARTMENT
JAN 21 1957
BUREAU OF MINES
ROBSTOWN

Mr. Herman Wood,
Trans-Pecos Minerals, Inc.
Robstown, Texas.

Dear Mr. Wood:

Subject: "Section 71", Fresnos Canyon,
Fowlkes Brothers Ranch,
Presidio County, Texas

In 1956, I spent several days on the Fowlkes Brothers ranch located in Presidio County, Texas, and during this time I made a reconnaissance trip down Fresnos canyon and looked at some portions of Section 71, particularly along the canyon. We looked at this area for faulting or other structure that might be favorable for either uranium or mercury mineralization. Carnotite or a closely related mineral species was found by one of the reconnaissance party members in an almost ashlike tuff. The material in which the carnotite occurs is rather widespread on this and other sections in the area, and also is rather thickly bedded. A hand dug sample from the discovery prospect was sent to Smith laboratory, Moab, Utah, and it was found to contain 0.142 U_3O_8 and 0.25 V_2O_5.

Aerial photographs of the area covering Section 71 and adjacent lands have been acquired and briefly studied; and published and unpublished open-file reports by United States Geological Survey members have been copied and studied.

I have also recently made a trip to the Raw Materials branch of the Atomic Energy Commission in Albuquerque, where I talked with Mr. H. D. Wolfe about the uranium possibilities of the Big Bend Area. At this time, lease agreements covering Section 71 between Trans-Pecos Minerals and Fowlkes Brothers, and Trans-Pecos Minerals and the Texas and Pacific Railroad were shown to Mr. Wolfe.

Mr. Wolfe indicated that a great deal of airborne reconnaissance had been performed in the Big Bend but that no anamoly maps had been issued. He also informed me that their office now has no field representative. Mr. Wolfe said that their geologist had not been able to check any localities in Fresnos canyon in 1956 since he had so much territory to cover. In view of this, some additional rough mapping will have to be performed since no detailed studies have been made of the section.

Mr. Wolfe and I also spent some time looking over the aerial photographs covering this section and adjacent lands. He was struck, as I am, with the evident faulting and particularly with the circular uplifts lying west and southwest of the Solitario Uplift. One or perhaps two of these uplifts may be on Section 71

In view of the encouragement given by Mr. Wolfe, and the finding of a uranium prospect on Section 71 in a type of material that is rather widespread, I believe that additional work should be performed right away. Some trenching and

augering should be done at the discovery prospect as an aid in determining the nature of the deposit and its extent. More prospecting should be done in order to find additional prospects on the section so that the probability of commercial tonnage will be increased. If this phase of the work should turn out to be encouraging, a more thorough exploration program should be undertaken using conventional and approved exploration techniques.

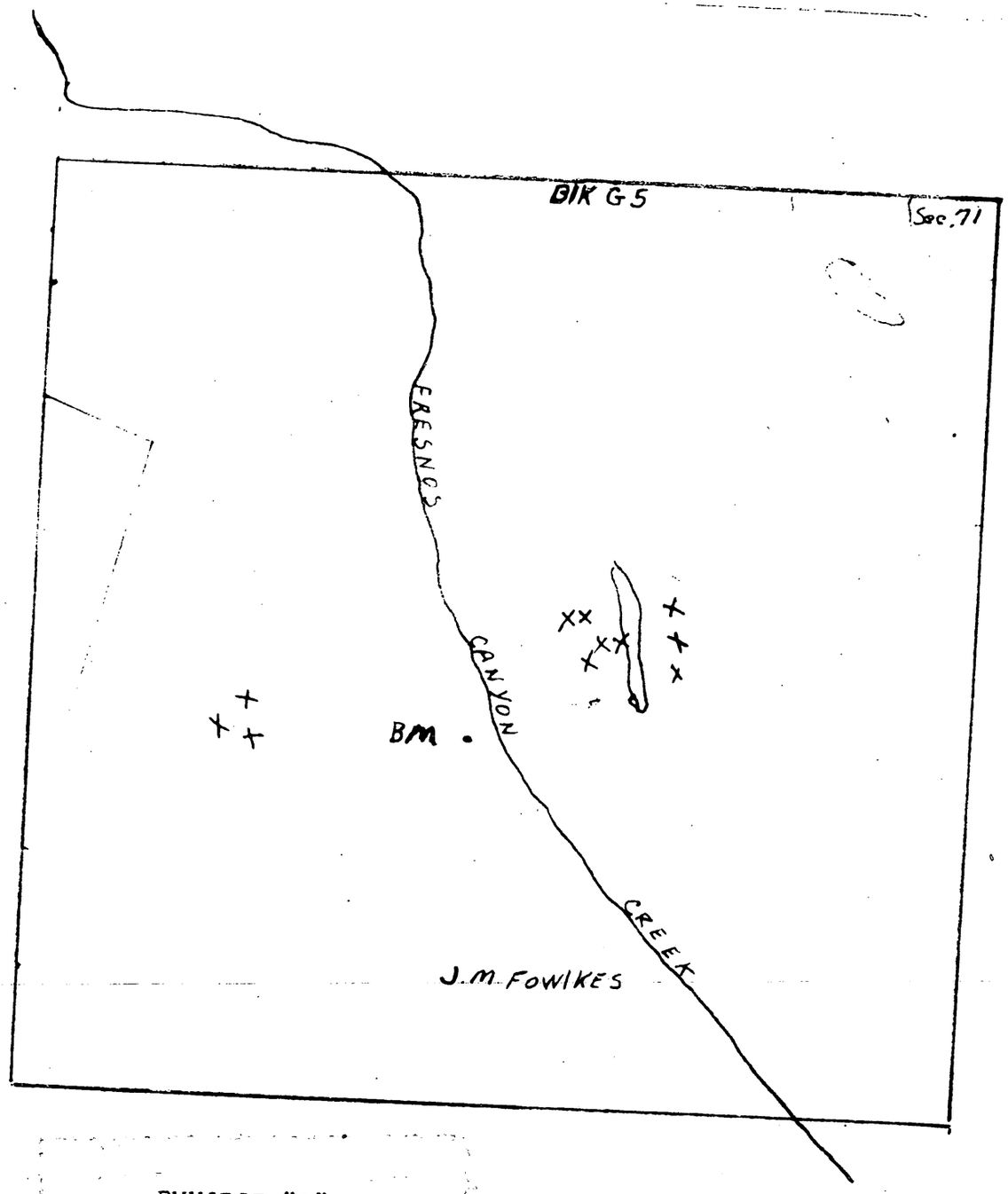
Nearby structural domes, if located on Section 71, should also be critically examined, and if geological conditions appear to warrant it, these should be explored by drilling for mercury and possibly for uranium.

Sincerely yours,

/s/ Carl Chelf

Carl Chelf

CC:cc



CERTIFICATE 505
ABSTRACT 3862
D & W RY SURVEY
Presidio Co TEXAS

EXHIBIT "F"

EXHIBIT "D"

Structural Geology of the Terlingua Quicksilver District, Texas

By

George A. Thompson, Jr.

RECEIVED
MINERALS TECHNOLOGY
DIVISION

JAN 21 1957

BUREAU OF MINES
JOPLIN, MO.

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Structural geology of the Terlingua quicksilver district, Texas

by George A. Thompson, Jr.

Abstract

Geologic mapping, supplemented by detailed investigations at the mines, has revealed new information about the geologic structure of the Terlingua quicksilver district, Texas. Attention is focused on the nature and origin of domes, grabens, and breccia pipes, structures that are unusually well developed in the area. The sedimentary rocks, of Cretaceous age, are overlain and intruded by igneous rocks of Tertiary age. Much of the structural deformation was an accompaniment of igneous intrusion.

The Terlingua uplift, an irregular dome with a structural relief of several thousand feet, covers about half of the district. The southern boundary of the uplift is a steep monocline. Smaller domes, found throughout the district, were formed by igneous uplift. Evidence for this origin includes exposures of the igneous rock, the occurrence of baked rock on the domes, and theoretical consideration of the forces necessary to form a dome.

Almost all the major faults are normal faults bounding depressed tracts, or grabens. Most of the major faults trend northwest; the strike varies markedly, with both sinuous curves and angular turns. The vertical displacement of the grabens below adjacent blocks varies up to approximately 2,000 feet. Minor faults belong to two sets; one set trends northwest, parallel to the major faults, and the other northeast.

Masses of breccia with a pipelike or chimneylike shape have been designated descriptively as breccia-filled pipes, or simply breccia pipes. A total of 76 breccia pipes was mapped, and four typical breccia pipes are described in detail. They range from 75 feet to 500 feet in diameter, and one has been explored vertically for more than 800 feet. The top of one breccia pipe has been found, in the Chinese mine, but the bottom of none has been found. The displacement of the fragments is downward, commonly several hundred feet, and in one instance more than 1,000 feet. The nature of the breccia and its walls indicates collapse due to undermining as the origin of the Terlingua pipes. Features, common to all the pipes, that point to this origin are the downward displacement of the fragments, the absence of drag or thrust structures, the presence of slump structures along the walls, and the vertical cylindrical form.

The general structural problems of the district include the age relations, the origin of the uplift, the origin of the domes, and the origin of the grabens. The earliest structural movement involving the Cretaceous rocks was the beginning of rise of the Terlingua uplift. Before this rise ceased, the graben faulting probably began. Volcanism and widespread hypabyssal intrusion, which was accompanied by doming, was partly contemporaneous with graben faulting. The breccia pipes were formed after the beginning, and before the end, of igneous activity. Minor faulting, accompanied by mineralization, continued later than other structural movements. The Terlingua uplift was probably caused primarily by laccolithic igneous intrusion but was influenced by horizontal compression. A basic intrusion, rather than a silicic intrusion, is required to explain the

exposed igneous rocks. The geometry of the large grabens indicates that they are relatively superficial accompaniments of horizontal extension. It is suggested that horizontal extension of the upper part of the earth's crust occurred during the formation of the Torlingua uplift and was accompanied by graben faulting.

Introduction

Location and accessibility

The Terlingua quicksilver district is in West Texas in the Big Bend region (fig. 1). Several areas of quicksilver mineralization lie in a mountainous semidesert area in the southern part of the Big Bend region. The main area of mineralization, comprising the Terlingua quicksilver district, is an east-west belt 21 miles long. The town of Terlingua lies near its center (fig. 2). Since the development of the Big Bend National Park, good roads have been built into the Big Bend region, and the Terlingua district is accessible by dirt roads connecting with the park roads.

Scope of the work

Because the Terlingua district affords an unusual opportunity to study certain geologic structures, particularly domes, grabens, and breccia pipes, this paper focuses attention on them. Other phases of the geology, including the ore deposits, petrography, and stratigraphy, are discussed only insofar as they have a direct and important relation to structure. A more comprehensive report on the geology and mineral resources of the district is in preparation for publication by the U. S. Geological Survey.

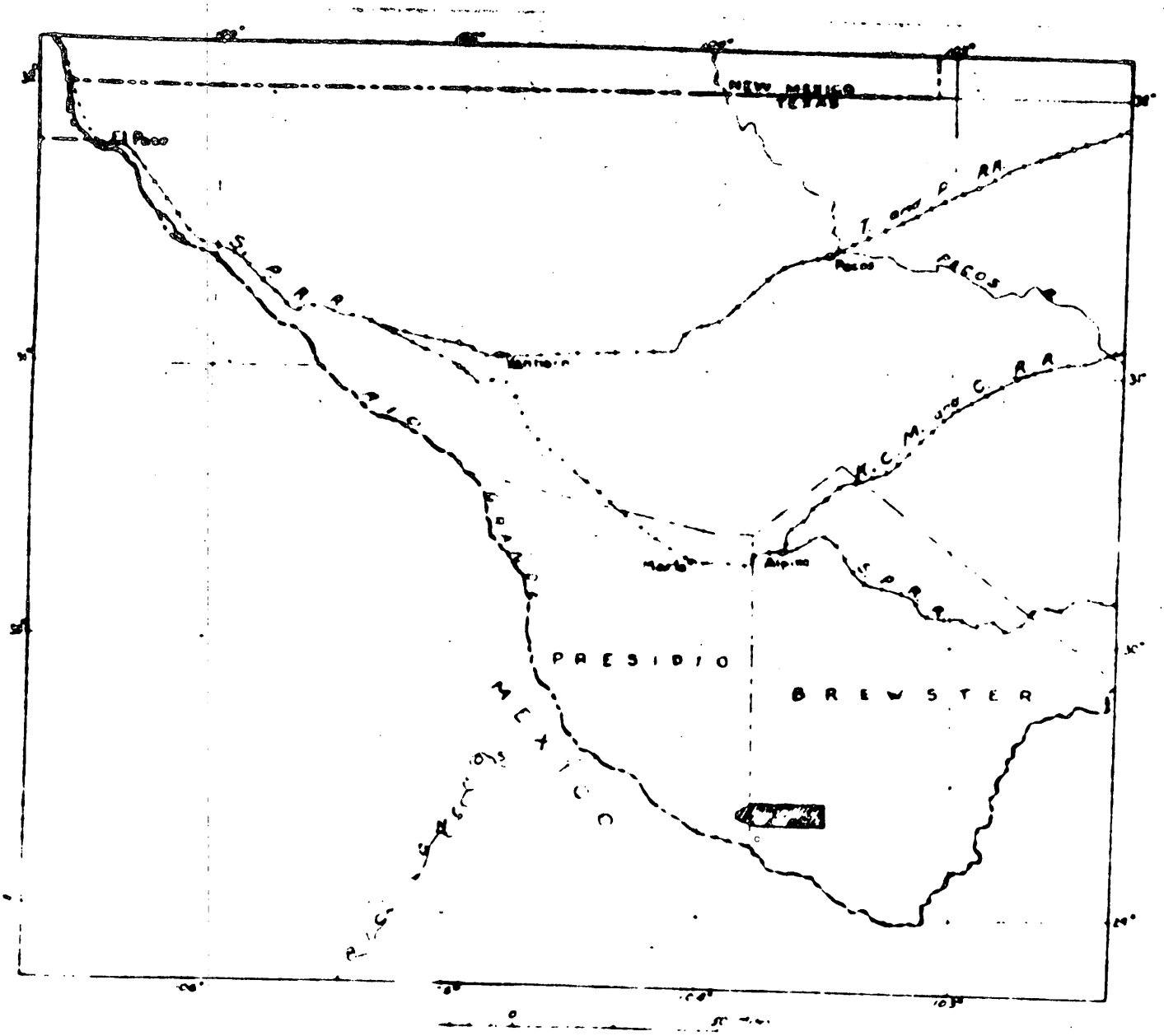

Figure 1.—Index map of western Texas showing location of the Terlingua quicksilver district (shaded).

Figure 2.—The town of Terlingua in 1943. The highest mountains in the background are the Chisos Mountains in the Big Bend National Park.

Field work and acknowledgments

The investigation, a portion of which is reported in this paper, was begun as a wartime strategic minerals investigation of the U. S. Geological Survey. Field work was carried on in the years 1942-1945. R. G. Yates, who was in charge of the project, and the writer each spent approximately 18 months on the field work. J. F. McAllister was with the party for 7 months in 1942. R. H. Bailey helped to complete the field work early in 1945. Randall Brown and Jaime Fernandez Concha assisted during the summer of 1943.

The unpublished work of C. P. Ross, who had spent approximately 6 months in a broad area that includes the Terlingua district, was made available and was especially helpful during the early stages of the geologic work.

A. C. Waters visited the writer in the field, and his suggestions have been most helpful. Thanks are due also to James Gilluly for a stimulating discussion of the problems in the field. The writer wishes to express here his appreciation also to the many other persons with whom the geologic problems have been discussed, and to the mine owners and mine personnel, who cooperated wholeheartedly.

General features

The Big Bend region

In the Big Bend region, vigorous erosion by tributary streams of the Rio Grande has carved the hard and soft rocks into boldly contrasting relief and effectively revealed their structure. The large-scale topographic features, which are likewise structural units, are: (1) the

Marathon Basin, (2) the lava-covered plateau south and west of Alpine, and (3) the topographically diverse mountains and intermontane areas of the southern Big Bend region. These features, though all were shaped by erosion, accurately reflect the folding, faulting and uplifting of sedimentary rocks that are in some places riddled by igneous intrusions and in other places buried by floods of lava.

The Marathon Basin 1/, in the northeastern part of the Big Bend region, is an erosional basin developed by the excavation of a broad structural dome more than 30 miles in diameter. The basin is underlain mainly by weak Paleozoic rocks and surrounded by escarpments of resistant Cretaceous limestones. The northern, eastern, and southern sides of the dome are tilted gently outward. The western side, according to King 2/, "is formed by the Del Norte and Santiago Mountains, which structurally constitute a single unit * * *. The rocks of the mountains are raised into a sharp monocline or anticline, overturned toward the west and broken in most places by an eastward dipping thrust fault."

West of the Marathon Basin and south and west of the town of Alpine, is the lava-covered plateau. This feature is actually a broad lava plain that extends over almost the entire northern and western part of the Big Bend region. Its evenness is interrupted by higher mesas and isolated mountains, which are erosional remnants of the higher lava flows, of igneous intrusions that pierce the lava flows, and of fault block mountains.

1/ King, P. B., Geology of the Marathon region, Texas: U. S. Geol. Survey Prof. Paper 187, 1937.

2/ King, P. B., op. cit. (U. S. Geol. Survey Prof. Paper 187), pp. 1[illegible], 13[illegible].

The southern part of the Big Bend region is carved on a scale both grand in broad scope and intricate in detail. The mountains are mostly bare rock, and the lowlands are covered with mountain waste. Folds, faults, and igneous intrusions are so abundant that even within a small area a large variety of rocks are exposed to the forces of erosion.

The main features of the southern part of the Big Bend region are the Chisos Mountains, the Solitario, Terlingua uplift, and Mesa de Anguila. The Chisos Mountains, 3/ the largest feature, are composed largely of lava flows and intrusions in the structurally low part of the southern Big Bend.

The most impressive feature of all is the Solitario. 4/ It is a high, mountain-rimmed basin that has been carved from a dome by erosional de-roofing of the Paleozoic rocks in its center (fig. 3). The Paleozoic rocks have been excavated more rapidly than the Mesozoic rocks of the rim, which dip steeply outward. The Solitario is noteworthy for its nearly perfect circular shape and its diameter of more than 7.5 miles. Structurally, it may be pictured as a high round dome located unsymmetrically atop a low irregular dome.

This low irregular dome is the Terlingua uplift, 5/ which extends south and east from the Solitario for a distance of at least 15 miles and forms the dominating structure of the Terlingua district.

3/ King, P. B., op. cit. (U. S. Geol. Survey Prof. Paper 187), p. 142.

4/ For a geologic map, see Sellards, E. H., Pre-Paleozoic and Paleozoic systems, Geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, fig. 9, p. 119, 1932; or Lonsdale, J. T., Igneous rocks of the Terlingua-Solitario region, Texas: Geol. Soc. America Bull., vol. 51, pl. 1, p. 1539, 1940.

5/ This feature has previously been called the Solitario uplift by Lonsdale and the Terlingua anticline by Ross, but to avoid confusion with the Solitario dome and to describe the structure adequately, the name Terlingua uplift is desirable.

Figure 3.—The southwestern flank of the Solitario dome.

South of the Solitario and the Terlingua uplift is the high Mesa de Anguila, a fault block the larger part of which is in Mexico. The northern boundary of this block, the Santa Helena Canyon fault, is a normal fault with a maximum displacement of thousands of feet.

Structural history of the Big Bend region.—The earliest deformation recorded in the Big Bend region involved only the Paleozoic and older rocks (fig. 4). Consequently, it is in evidence only in the Marathon Basin and the Solitario, where the Paleozoic rocks are not covered by Cretaceous and later rocks. The Paleozoic rocks of the Marathon Basin and the Solitario are strongly folded and thrust faulted along northeast trends. The northern limit of the folded area is exposed in the Marathon Basin and by drill-hole data 6/ can be traced eastward under younger rocks. Farther east it curves and apparently joins the west margin of the Ouachita folded belt. 7/ The similarly folded Marathon-Solitario and Ouachita belts therefore probably constitute one belt of deformation that extends at least from western Texas to Arkansas but over much of its extent is buried. King 8/ believes that the deformation in the Marathon basin culminated at the end of the Pennsylvanian epoch.

Cretaceous rocks rest on the eroded edges of the Paleozoic rocks. After deposition of Cretaceous rocks, further folding and faulting took place. The broad uplift of the Marathon dome occurred after deposition of the Upper Cretaceous rocks found on its flanks, and probably in part after the Tertiary volcanic eruptions. 9/ About the same time, the

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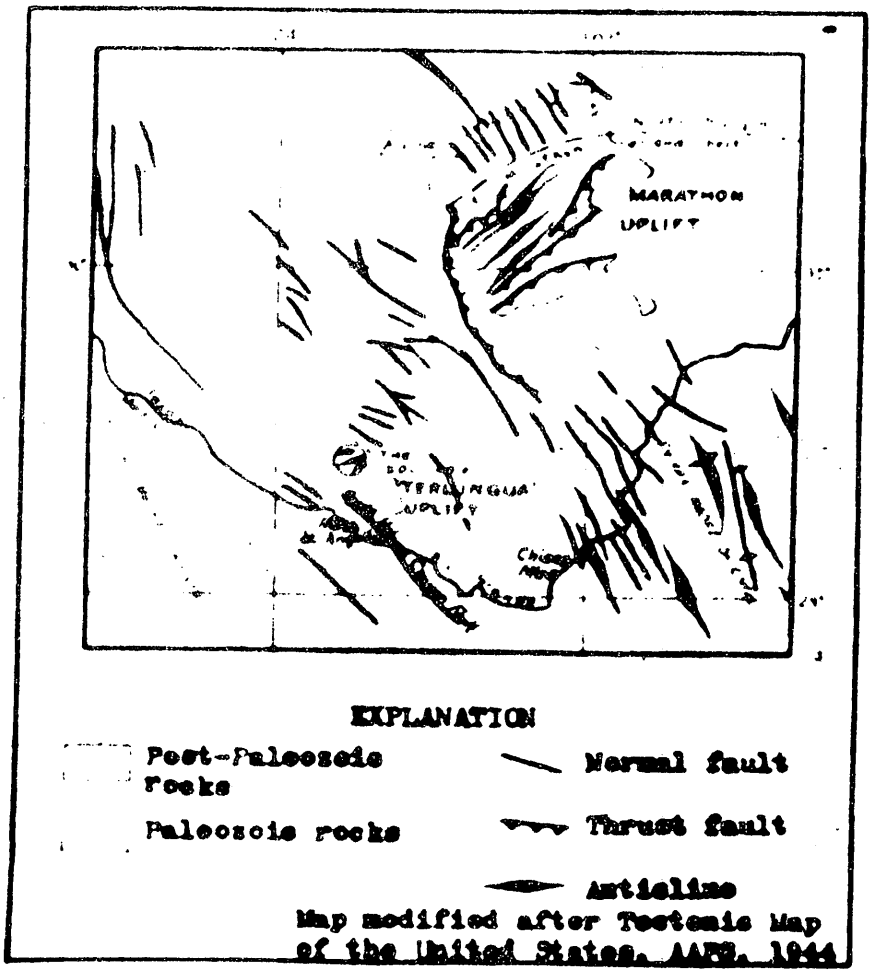
6/ Sellards, E. H., op. cit. (Bull. 3232), fig. 10, p. 128. See also Amer. Assoc. Petroleum Geologists Tectonic Map of the United States.

7/ Ellison, S. P., and Sellards, E. H., Pre-Cretaceous rocks found in wells in Gulf Coastal Plain south of Ouachita Mountains, Amer. Assoc. Petroleum Geologists Bull., vol. 15, pp. [illegible], 1931.

8/ King, P. B., op. cit. (U. S. Geol. Survey Prof. Paper 215), p. 134.

9/ King, P. B., idem., pp. 139-140.



REGIONAL STRUCTURAL TRENDS

FIGURE 4

Faults and folds trending northeastward are pre-Cretaceous, and mainly pre-Permian, in age; those trending northwestward are post-Cretaceous in age. The pre-Cretaceous structures, revealed only in the Marathon and Solitario uplifts, differ in type as well as in trend from the post-Cretaceous structures.

Solitario dome and the Terlingua uplift were formed. This deformation was probably contemporaneous with the formation of the northwest trending anticlines of the Sierra Madre Oriental, typically developed in Mexico east and west of the Big Bend region. Thus the post-Cretaceous deformation was characterized by trends at nearly right angles to the northeast trending pre-Cretaceous structures.

King's observations, as well as those of the writer, indicate that the normal faulting, which is so prominent in much of the region, is generally younger than the major folding.

Igneous intrusion, minor faulting, the formation of breccia pipes, and ore deposition, took place after the period of major normal faulting.

The Terlingua district

Rocks.—The sedimentary rocks in the district are separated into formations that are generally easily recognizable. The stratigraphic nomenclature used is that of Ross. 10/ The most important data on the sedimentary rocks are summarized in figure 5. (See also figures 6-11, inclusive.) The Boquillas flags were divided into an upper and a lower member at the base of a dark-brown arenaceous limestone bed about a foot thick. This bed is not lithologically unique, but it can be distinguished from the few beds that resemble it by the presence of an ammonite with short spines, Criocerras n. sp. 11/ The base of the Criocerras bed is shown on plate 1 as a dotted boundary because in many places it could not be located accurately beneath slope wash and other shallow cover.

10/ Ross, C. P., The quicksilver deposits of the Terlingua region, Texas: Econ. Geology, vol. 36, p. 121, 1941.

11/ Sellards, E. H., Adkins, W. S., and Plummer, F. B., Geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, p. 451, 1933.

	FORMATIONS IN WESTERN PART OF TERLINGUA DISTRICT	FORMATIONS IN EASTERN PART OF TERLINGUA DISTRICT	EQUIVALENTS, AFTER ROSS
TERTIARY and UPPER CRETACEOUS	CHISOS VOLCANICS 100 FT.+	(removed by erosion)	
UPPER CRETACEOUS	ABSENT BY ANGULAR UNCONFORMITY, WHICH IS OVERLAIN BY CHISOS VOLCANICS	TORNILLO CLAY 600 FT.+	NAVARRO AGE
		AGUJA FORMATION 1000 FT.	TAYLOR AGE
		TERLINGUA CLAY 1050 FT.	AUSTIN AGE
	BOQUILLAS FLAGS, LOWER MEMBER	BOQUILLAS FLAGS UPPER MEMBER 600 FT. BOQUILLAS FLAGS LOWER MEMBER 400 FT.	EAGLE FORD AGE
	GRAYSON FORMATION 170 FT.	GRAYSON FORMATION 170 FT.	WASHITA GROUP
LOWER CRETACEOUS	DEVILS RIVER LIMESTONE 1500 FT.+	DEVILS RIVER LIMESTONE 1500 FT.+	FREDERICKSBURG GROUP

FIGURE 5
STRATIGRAPHIC COLUMN, TERLINGUA DISTRICT, TEXAS

Figure 6.—A hill of Orliaga clay in Long Draw, showing characteristic erosion form of this formation.

Figure 7.—Upper member of Boquillas flags, consisting of shale with a few hard calcareous beds.

Figure 8.—Lower member of Boquillas flags, consisting of impure calcareous beds interculated with shale. The dark rock in the center of the photograph is a sill of igneous rock.

Figure 5.— [illegible] limestone, [illegible] California Hill, [illegible] top of [illegible] formation, of which the slopes [illegible] contoso.

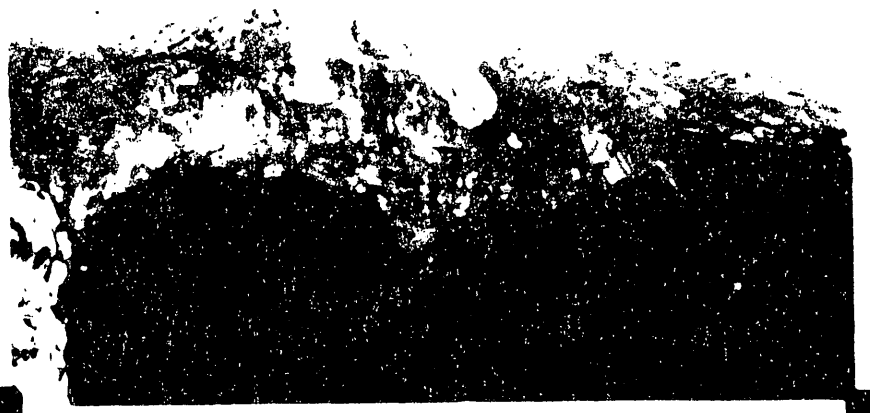


Figure [illegible].— [illegible] [illegible] over limestone on the [illegible] bank of the Solitario.

Figure 11.—Devils River limestone folded in a monocline near Maggie Sink.

The igneous rocks of the district include many kinds of intrusive rocks and a very small area of extrusive rhyolitic and andesitic rocks. Lonsdale 12/ has studied the petrography of the larger intrusions and subdivided the intrusive rocks into an analcite-bearing group and a group without analcite. Both groups range from basic to silicic.

Structure.—The structure of the Terlingua district, here taken as the mapped area, is dominated by large domes and grabens. On a smaller scale the rocks have also been irregularly deformed by intrusions, offset by innumerable faults, and broken by collapse structures, especially breccia pipes. The Terlingua uplift, the largest domical structure, extends beyond the district. Its abruptly flexed southern margin, which is referred to as the Terlingua monocline, is a distinct structural feature that extends from the western limit to the eastern limit of the district. A number of smaller domes, some of which are superimposed on the Terlingua uplift, are prominent structural features of the district. Several grabens, the longest of which is Long Draw graben, break the continuity of the Terlingua uplift. Hypabyssal intrusions of many different shapes have invaded the sedimentary rocks and have an important bearing on the structural geology because of the deformation that accompanied their emplacement. Small faults and fractures are numerous in most parts of the district; they are perhaps best shown by the drainage pattern on the higher parts of the Terlingua uplift, where erosion has emphasized them in the exposed limestone (fig. 12). In some areas solution of the limestone has caused collapse, which is not limited to the limestone but

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12/ Lonsdale, J. T., op. cit., Geol. Soc. America Bull., vol. 51), p. 1[illegible].

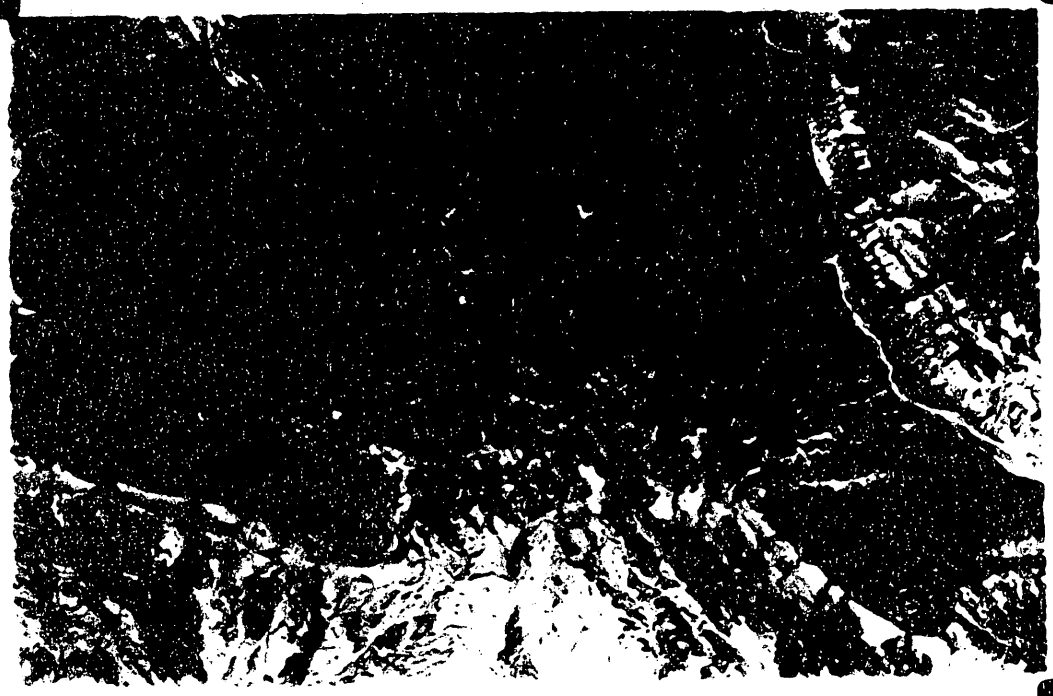

Figure 12.—Airplane photograph, taken vertically, of part of the Terlingua district. North is toward the top, scale about 1/50,000. The dark rock covering most of the area is Devils River limestone, upon which erosion has strikingly accentuated the pattern of fractures and faults. The sinuous Terlingua monocline can be seen extending across the southern part of the area, and the Long Draw is conspicuous near the eastern edge. Courtesy U. S. Army.

extends upward into the overlying rocks. Breccia pipes, exposed most abundantly on the Terlingua uplift, are one of the most interesting geological features of the district. The grabens—long, relatively narrow downfaulted blocks—intersect the Terlingua monocline, which bounds the Terlingua uplift on the south. Flat-bottomed, steep-walled canyons such as the Long Draw and Wall Creek Valley are topographic expressions of these grabens. The general trend of the grabens is northwest; an exception is the Black Mesa graben zone, which strikes northeast. As major structures, all the grabens die out along the Terlingua monocline, which thus serves as a hinge line for the graben faults.

Lifting and pushing by igneous intrusion has clearly deformed the rocks of the Terlingua district. Sills and laccoliths made way for themselves by lifting and shouldering aside the enclosing strata; plugs and dikes also caused deformation, although in some cases they may have pushed into preexisting openings. Monoclinal flexures over the margins of sills and laccolithic domes are prominent examples of deformation by intrusion (fig. 23).

The small faults and fractures are of two main trends: a northwest trending group parallel to the major grabens and block faults, and a northeast trending group with which the ore is associated.

The solution caverns originated by irregular enlargement along fractures and bedding planes in the limestone. The solution effects are generally most noticeable at the top of the Devils River limestone, where the overlying, incompetent Grayson formation has slumped into the caverns (figs. 38, 39, 40). The resulting cave-fill zones resemble normal synclines locally and might be mistaken for tectonic folds.

The breccia pipes crop out as roughly circular areas containing jumbled fragments of rocks from higher formations (figs. 34, 35, 36). Downward exploration of several of these breccia areas has proved them to continue almost vertically and thus to be truly pipelike in form. Several of the breccia pipes contain intrusions, which were emplaced subsequent to the formation of the breccia. A few are mineralized by cinnabar.

The Terlingua uplift

The Terlingua uplift covers roughly half of the Terlingua district, as mapped in plate 1. It extends from the Fresno mine near the western end of the map eastward beyond Long Draw and finally plunges, gradually losing its identity in the eastern part of the district. Its southern limit is the Terlingua monocline, which is traceable from the northwestern corner of the district map to the southeastern corner, and its northern limit is beyond the edge of the map. The higher part of the uplift is west of Long Draw. The regional relations of this elongate domical structure have been commented upon by Ross, 13/ Lonsdale 14/ and others.

Figure 13 illustrates the general outline and size of the Terlingua uplift and the Solitario dome; the two of them constitute a single composite unit approximately 20 miles long and 5 to 10 miles wide. The rocks along the northeastern border of the Terlingua uplift have dips that range from less than 10° to about 20°. 15/ The southwestern border, on the other hand, is the Terlingua monocline, along which the steepest beds have an average dip of 45°. The top of the uplift is relatively flat, with a slight eastward plunge.

13/ Ross, C. P., The quicksilver deposits of the Terlingua region, Texas: Econ. Geology, vol. 36, pp. 115-142, 1941.

14/ Lonsdale, J. T., Igneous rocks of the Terlingua-Solitario region, Texas: Geol. Soc. America Bull., vol. 51, pp. 1539-1626, 1940.

15/ Ross, C. P., unpublished manuscript.

The difference between the elevation of the rocks in the Terlingua uplift and the surrounding area is measured in thousands of feet. The top of the Devils River limestone on Reed Plateau (pl. 1) is approximately 3,400 feet above the same horizon four miles to the east and south (two miles south of Cigar Mountain). Midway between Reed Plateau and the Solitario the comparable displacement is about 4,600 feet. It is estimated, from Ross' map 16/ and the geologic map of the Solitario by Sellards, Adkins, and Arick, 17/ that the displacement of the Solitario above the Terlingua uplift is at least 3,500 feet. Thus the composite vertical displacement of the Solitario dome and Terlingua uplift is roughly 8,100 feet. If the area just southwest of the Solitario were chosen as a basis for determining displacement, instead of the area south of Cigar Mountain, the composite displacement would be 6,700 feet instead of 8,100 feet. These displacements may be compared to the displacement of 5,500 feet or more in the Marathon dome 18/ and 9,000 feet in the Black Hills uplift. 19/

16/ Ross, C. P., unpublished manuscript map.

17/ Sellards, E. H., Adkins, W. S., and Arick, M. B., Geologic map of the Solitario: Bureau of Economic Geology, University of Texas, 1933. This map is published on a reduced scale and in modified form in Sellards, E. H., op. cit. (Bull. 3232, p. 119), and also in Lonsdale, J. T., op. cit., Geol. Soc. America Bull., vol. 51, p. 1539).

18/ King, P. B., op. cit. (U. S. Geol. Survey Prof. Paper 187), p. 138.

19/ Darton, N. H., and O'Harra, C. C., U. S. Geological Survey Geol. Atlas, Folio (Belle Fourche No. 154), p. 3, 1909.

The Terlingua monocline

The Terlingua monocline comprises the southwestern and southern flank of the Terlingua uplift. It is the zone of steep southward dipping rocks in which the beds rise thousands of feet to the flat-topped Terlingua uplift in a horizontal distance averaging less than half a mile (fig. 14). Beyond the Terlingua district to the northwest, this monocline merges into the southwestern flank of the Solitario dome. Throughout much of its length, it is marked by the narrow outcrop belt of the Buda limestone and Grayson formation, but it continues undiminished in magnitude east of Long Draw, where these rocks are concealed by younger rocks. Near the eastern end of the district (southeast of Maverick Mountain) the monocline loses its identity in an area of erratic strikes and dips, but the possibility that it extends eastward beyond the district, obscured by younger sediments, should not be overlooked.

These findings in regard to the structure of the Terlingua monocline and Terlingua uplift differ from those of Ross 20/ who did not recognize the eastward extension of the monocline but treated the Terlingua uplift as an anticline that turned southward near Terlingua. Of this southward part Ross says, 21/ "This anticline is somewhat ill-defined where it crosses the Rio Grande." In the Terlingua region, an area of vulcanicity, uplifts, large faults, and many intrusions, it is difficult in many places to define definite structural units such as anticlines. The Terlingua

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20/ Ross, C. P. Quicksilver lodes of the Terlingua region, Texas: Ore deposits as related to structural features (Editor, Ruhlman, W. R.), p. 193-195. 1942; The quicksilver deposits of the Terlingua region, Texas: Econ. Geology vol. 36, pp. 115-142, 1941; Preliminary report on the Terlingua quicksilver district, Brewster County, Texas: Texas Univ. Bull. no. 3401, pp. 558-568, 1934.

21/ Ross, C. P. op. cit. (Ore deposits as related to structural features), p. 193.

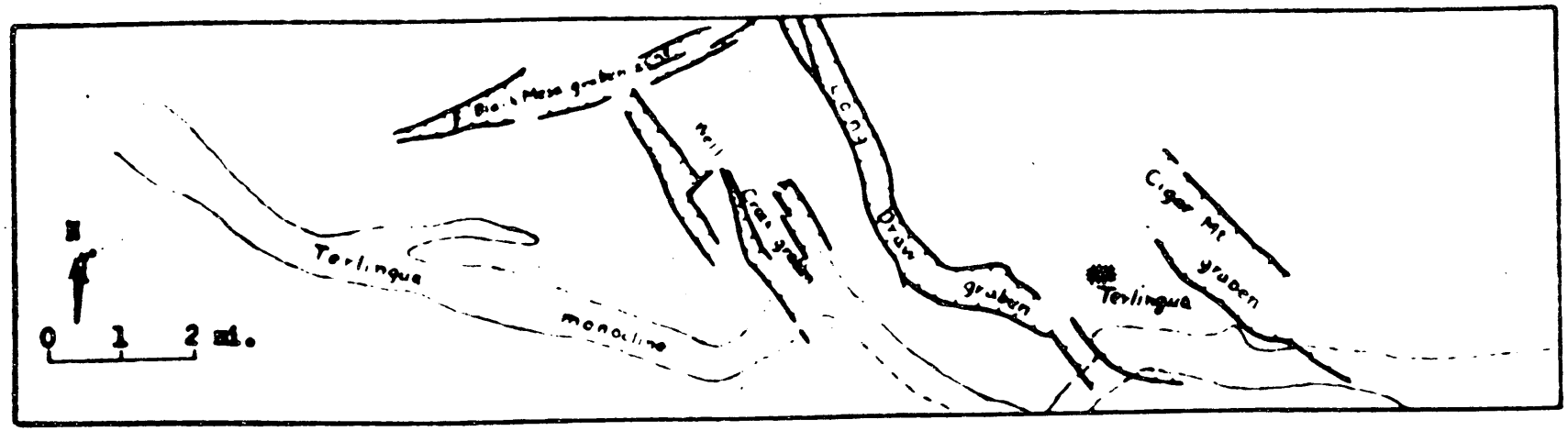

FIGURE 14

GENERALIZED STRUCTURE MAP OF TERLINGUA DISTRICT, SHOWING TERLINGUA MONOCLINE AND PRINCIPAL GRABEN.

The monocline is delimited as a zone of southerly dips exceeding 15.°

Limit of zone of southerly dips exceeding 15°

Normal fault, showing downthrown side

monocline, however, is a remarkably distinct and continuous structure at least throughout the Terlingua quicksilver district, and it forms a clear-cut southern boundary to the structure herein called the Terlingua uplift.

The various features of the portion of the monocline within the Terlingua district are taken up in geographic order from west to east. At the northwest corner of the Terlingua district, the monocline is a folded zone more than a mile wide involving in its outcrop the Devils River limestone, the Grayson formation, the Buda limestone, and the Boquillas flags (pl. 1). The strike averages N. 35° W. and the westward dip is as much as 40° (fig. 15). A remnant of the Chisos volcanics is left on a high hill along this part of the monocline. This remnant of Tertiary rocks is composed of a series of flat-lying beds of tuff and conglomerate, about 30 feet thick, overlain by rhyolitic rocks. It is especially significant for the information about age relations that it affords. The basal conglomerate lies on the upturned and beveled edges of the Boquillas flags, which dip between 10° and 35° in this part of the monocline. The monoclinal folding and considerable erosion must have taken place before deposition of these Chisos volcanics. Movement later than the deposition of the volcanics is recorded, however, in the irregular eastward dip at the eastern end of the remnant 22/ and in the small outlier east of the main remnant. Here the Chisos volcanics are slumped, possibly because of solution in the underlying Devils River limestone. Extensive solution features are apparent in the adjacent Fresno mine area. Similarly, downdropped blocks of the volcanics are preserved in the numerous breccia pipes in the Fresno mine area.

22/ The dips here are too local to be shown on plate 1.

Figure 15.—The Terlingua monocline at the Fresno mine, northwestern part of the Terlingua district.

Just east of the Presidio-Brewster County line, the monocline curves abruptly eastward. Here a number of faults strike within 20° of east-west, and these faults are noteworthy because they show an unusual amount of strike-slip and reverse movement for the Terlingua district. The southernmost fault in the zone is a reverse fault dipping about 50° N.

The faults on the eastward extension of this fault zone show only normal movement. The fault zone is north of and roughly parallel to the sinuous eastward course of the monocline, and along the zone are a number of intrusions and breccia pipes and a downfaulted synclinal area (on the north side of the monocline west of Maggie Sink; see plate 1). The largest intrusion is an elongate dikelike or plugline mass, whose contacts are almost entirely covered by alluvium. A breccia pipe at the north end of this intrusion contains blocks of Buda limestone, igneous rock, and clay. Half a mile east of the intrusion there is a large, poorly exposed area of breccia containing fragments of Buda limestone, Grayson formation, and igneous rock; the igneous rock is probably part of the Chisos volcanics that once overlay this area. A mile farther eastward, remnants of Buda limestone and Grayson formation are preserved in the downfaulted synclinal area (fig. 16). Three breccia pipes and one small intrusion crop out in this area.

From the downfaulted syncline eastward to Tres Cuevas Mountain and beyond, the monocline is paralleled by an anticline north of it and by a syncline north of the anticline. The monocline near Tres Cuevas is a half-mile wide zone of southerly dips ranging from 20° to 70° (fig. 19).

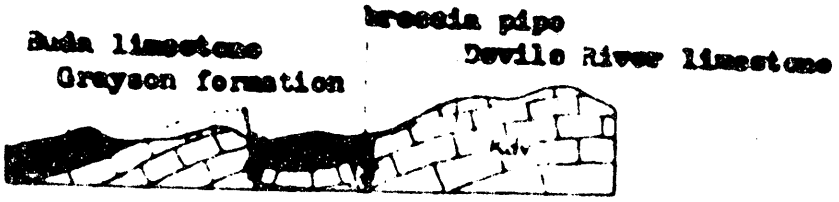

FIGURE 16

Vertical section across the Terlingua monocline west of Maggie Sink. Scale: 1/25,000 (1 inch equals approximately 0.4 mile)

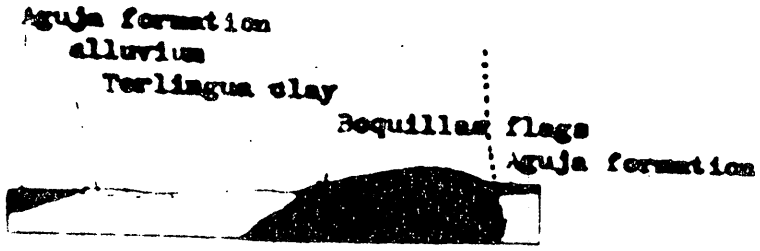

FIGURE 17

Vertical section across Terlingua monocline at Questa Blanca. Scale: 1/25,000 (1 inch equals approximately 0.4 mile)

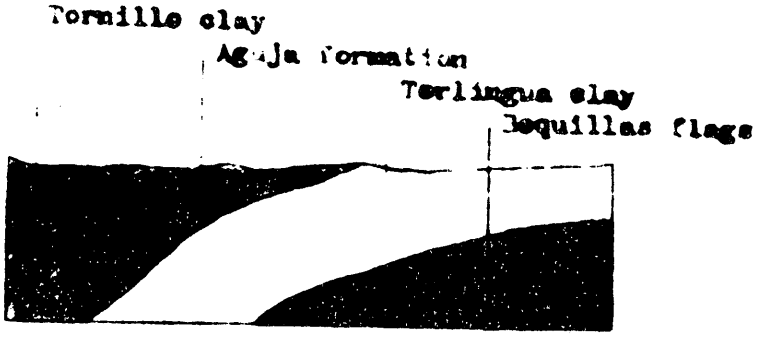

FIGURE 18

Vertical section across Terlingua monocline south of Maverick Mountain. Scale: 1/25,000 (1 inch equals approximately 0.4 mile)

Figure 6.— The Torlesque monocline east of Cross Davis Mountain. The Chisos Mountains are in the background.

From Tres Chevas Mountain, the monocline extends eastward for 1½ miles with an average strike of S. 70° E. and southward dips of 60° in the steepest beds. In the area south of the Mariposa mine the monocline makes a major curve to a new strike of about N. 65° E., which continues for 1½ miles and crosses the fault zone of Well Creek Draw (pl. 1 and fig. 12). This northeast trending sector of the monocline is flatter on the average, although the steepest beds dip as much as 60°. The Well Creek graben faults can be traced southward to the monocline, where their displacements are negligible compared to their displacements on the Torlingua uplift to the northwest. This generality may be extended to all the graben and block faults that are so prominent on the Torlingua uplift, for they all weaken greatly or die out where they intersect the monocline.

South of the Waldron and Little Thirty-Eight mines, the monocline again makes an abrupt change in strike from N. 65° E. to about S. 50° E., and this new trend continues southeastward along Reed Plateau (pl. 1 and fig. 12). The steepest beds just east of the change in strike are dipping only 25°, but 1½ miles to the southeast, along the southwestern edge of Reed Plateau, they have steepened to 75° and locally even more. Here the monocline is a zone with steep dips only a little more than half a mile wide.

From Reed Plateau the monocline extends about S. 30° E. The vertical displacement decreases on this trend, however, because part of the displacement is taken up on a secondary monocline trending N. 55° E. from the south end of Reed Plateau and having dips of only about 10°. The southward limit of the main monocline is buried in alluvium, and thus the width, steepness and amount of faulting of the fold are unknown. Three low-angle thrust faults in this area dip southwest and approximately parallel

the monocline (pl. 1). In their well-exposed portions they displace the rocks vertically less than 100 feet, but the displacement may be larger under the alluvium to the southeast.

The monocline turns northeast along the southern border of the mapped area, south of the town of Torlingua. Across the southeastern end of the Long Draw it has a trend of about N. 35° E., and the steepest beds average 30° in dip. The fault zone of the Long Draw graben, diminished in displacement, crosses the monocline and dies out. Long Draw is the site not only of graben faulting but also of differential displacement between the blocks east and west of it. That is, the eastern block is structurally lower than the western, and the graben block between them is lower still (pl. 1, section AA').

The Torlingua monocline strikes approximately S. 80° E. from Long Draw to Cuesta Blanca. The steepest beds dip on an average 30° to 35° S. (fig. 17). A thrust fault one mile south of Cigar Mountain, with a strike of N. 20° W. and a dip of 20° to 30° W., extends southward only a short distance into the folded beds of the monocline and there dies out.

Cuesta Blanca is a notable hill of Boquillas flags baked gray by a concealed intrusion, and thus being in marked color contrast to the normal tan of the weathered rock. The structure of the hill, doubtless due to the same concealed intrusion, is that of a dome, broken on the northeastern side by the Cigar Mountain graben and steepened on the southwestern side by coincidence with the monocline. The monocline, thus modified, swings around Cuesta Blanca as though the latter were a blunt instrument pressed southwestward. The result is a monoclinal trend of S. 55° E. on the southwestern side of Cuesta Blanca, changing to N. 70° E. on the southeastern side.

The southwest fault of the Cigar Mountain graben diminishes in magnitude southeastward and has a relatively small displacement where it crosses the monocline. It probably dies out within the zone of monoclinal folding; the other fault bounding the graben dies out north of the monocline.

The monocline continues its northeastward trend from Cuesta Blanca across the southeastern end of the Cigar Mountain graben and then swings to a trend of almost due east. South dips between 35° and 40° characterize a zone more than half a mile wide, but the total width is not known because the southern limit is outside of the area mapped. East of Cuesta Blanca the monocline is topographically less conspicuous than it is to the west, because the rocks that compose it are more uniformly weak against the forces of erosion. Nevertheless the structural relief of the monocline is as great here as in the western part of the district. For example, the structural relief south of Maverick Mountain is more than 2,000 feet (fig. 13), as compared to 1,600 feet at Reed Platform (pl. 1, section AA'). The only difference is that the monocline, as exposed, is in stratigraphically higher rocks in the eastern part of the district because of the gradual eastward plunge of the beds.

South of Maverick Mountain, the monoclinal structure is obscured by several faults that form a poorly exposed, northeastward trending graben of small displacement. In this area the monocline shows a tendency to swing northeastward as shown by strikes of N. 65° E. in some of the beds. This change is similar to the change in trend of the monocline at its intersections with the other northeast trending grabens. Dips are more gentle south of Maverick Mountain, the steepest dips averaging about 30°. The monocline is almost completely covered by alluvium immediately east of the Terlingua district.

Domes

Domes, ranging in diameter from one to three miles, are described by geographic location, beginning at the western end of the Terlingua district. All the domes are probably genetically related to intrusions.

Wax Factory laccolith and dome

Only part of the Wax Factory laccolith 23/ extends into the western edge of the district. This interesting intrusion, being thoroughly dissected, reveals the doming, crumpling, and offsetting of the intruded beds that took place as the magma made way for itself (figs. 20, 21, 22). It shows in greater detail than elsewhere the origin of the laccolithic domes in the district. The large area of igneous rock at the western extremity of the district (pl. 1) is the thinning eastern edge of the laccolith. Remnants of the top contact are preserved in the small patches of overlying Boquillas flags, and a projection of the top and bottom contacts indicates that the eastern edge is not eroded back very far but is nearly at its former limit. The intrusion has baked and hardened the intruded sediments for various distances.

Contrabando dome

Southeast of the Wax Factory laccolith is a broad domical structure, Contrabando dome. It is more than two miles in diameter and has a structural relief of approximately 500 feet. The dome is crossed by a number of small faults of northeast and northwest trends characteristic of faults in the entire district. Rhyolite dikes and plugs are intruded discontinuously along two faults; other rhyolite plugs are scattered over the dome, and a large

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23/ Lonsdale, J. T., op. cit. (Geol. Soc. America, Bull., vol. 51, p. 1554.

Figure 20.—Part of the dissected Wax Factory laccolith west of the Fresno mine. The Doquillas flags are below for greater distance above than below the intrusion.

Figure 21.—Upper contact of part of the Wax Factory laccolith. The Doquillas flags above the intrusion have been distorted locally by the thrusting and crushing of the intrusion process.

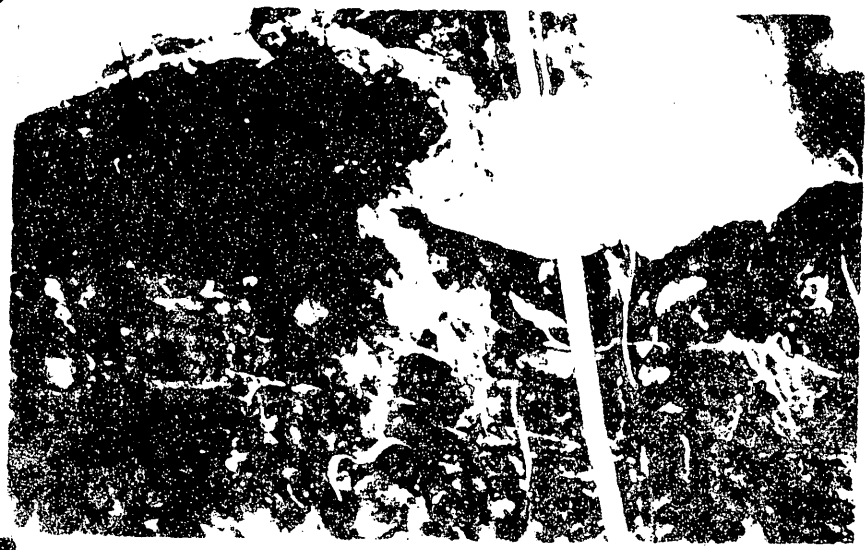

Figure 22.—Detail of [illegible] the Wax Factory [illegible] photograph shows scale. [illegible] in the igneous rock are chalcedony [illegible].

rhyolite sill is exposed at the eastern extremity of the dome. The Boquillas flags are baked throughout the area where most of the dikes and plugs are exposed. As dikes and plugs elsewhere in the district have not baked the surrounding rocks for such great distances laterally, the baked rock here must indicate a more widespread intrusion below, probably a laccolith or sill. This concealed intrusion, indicated only by an expanse of baked rock, is very likely the cause of the dome.

Black Mesa dome

The Black Mesa dome is 2½ miles northwest of the Mariposa mine and adjacent to Lewis Valley. This flat-topped dome is 1½ miles in diameter and has a structural relief of 600 feet (fig. 41). The northwest one-quarter of the dome has been destroyed by downfaulting into the chaotic structure of Lewis Valley. All available evidence indicates that the dome was once complete before being broken by the Lewis Valley structure; that is, the dome is abruptly broken off, and the faults on the flanks of the dome are not deflected in strike or dip as they would have been if the dome were the later structure.

The Black Mesa dome was probably formed through lifting of the sedimentary rocks by igneous intrusion, but no direct evidence of the presence of an intrusion under the dome was found. The theoretical possibility of this kind of dome being formed by horizontal stresses is discussed and rejected in the section on general structural problems.

Long Bone dome

The southern third of a dome lies within the Terlingua district at the northern end of Long Bone. Its northeastern flank merges with the mono-

45

clinal northeastern border of the Terlingua uplift. The dome is three miles in diameter and has a structural relief of 300 or 400 feet. The part within the district is a crescent-shaped belt of beds dipping 10° to 30° S. on both sides of, and within, the Long Draw graben.

Terlingua dome

Immediately northwest of Terlingua is a low irregular domical structure half a mile by 1¼ mile in area. The origin of this structure is revealed by its coincidence with an area of baked rocks and by one large and three tiny outcrops of intrusive igneous rock within the area. A core-drill hole near the southeast end of the baked area revealed an igneous sill, which is shown in sections AA' and BB', plate 1. The southwestern and northwestern flanks of the dome are abrupt and steep, with dips exceeding 35° not uncommon. This steep border may be compared genetically with a better-understood fold at Study Butte, where mine workings revealed subsurface structure. Figure 23 illustrates the origin of the Study Butte fold. The intrusion beneath the Terlingua dome is perhaps less discordant than the Study Butte intrusion, as the latter was intruded into rocks with poorer bedding.

The northeastern border of the Terlingua dome is more gentle, as though formed by a gradual thinning of the sill northeastward; dips do not exceed 15° except locally along a fault, which is probably also contemporaneous with intrusion. The elongation of the structure is parallel to the Long Draw graben and to the Terlingua monocline along Reed Plateau.

Two-Forty-Eight dome

East of the Cigar Mountain graben and the Two-Forty-Eight mine is a broad low dome similar in size and shape to the Gambhamite dome. The upper member of Boquillas flags is exposed over most of the domical area, and it is surrounded on three sides by the overlying Terlingua clay and on the fourth by the graben. The dome has a diameter of two to three miles, marginal dips up to 15°, and a structural relief of roughly 500 feet. Uplift by a sill or broad laccolith is the inferred cause of the dome. One sill was penetrated in the Two-Forty-Eight mine at a depth of 500 feet, but it may not be of adequate thickness and distribution to explain the dome.

Grabens

Almost all the major faults of the Terlingua uplift are steeply dipping normal faults bounding depressed tracts, or grabens (fig. 14). The grabens are narrow compared to their length; for example, the Long Draw graben is more than 12 times as long as it is wide. In general the major faults trend northwest, but there is a notable exception in the Black Mesa graben zone, whose bounding faults trend northeast (pl. 1). The strikes of the graben faults vary markedly; the faults have both sinuous curves and angular turns. In detail the faults are en echelon; in many places they form irregular zones rather than single fault planes (fig. 24). Were the floors of the grabens better exposed, the complexity of the fault pattern would be even more in evidence. The maximum vertical displacement of the grabens below adjacent blocks is approximately 2,000 feet, or about equal to the vertical displacement across the Terlingua monocline.

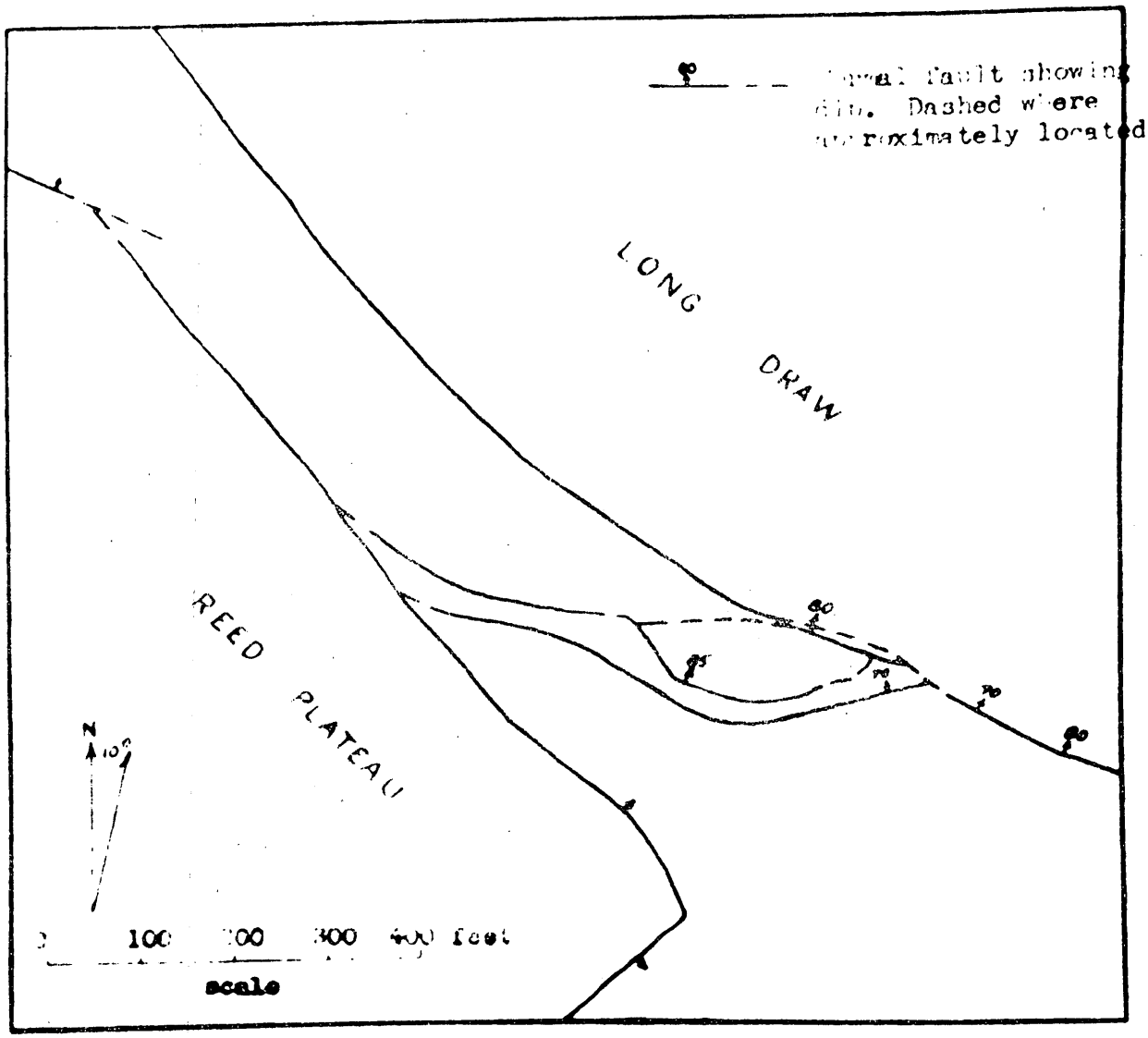

FIGURE 24

Detailed map of the normal faults bounding the southwestern side of Long Draw south of the Chisos mine. The rocks in Long Draw are displaced downward over 2000 feet relative to the rocks in Reed Plateau. The displacement, divided between two faults in the northwestern part of the map, is concentrated in one fault at the eastern edge of the map; the transition occurs in a zone of converging faults and in locally tilted beds.

Long Draw graben

Long Draw graben is the largest. It has a length of more than six miles, and an average width of about half a mile. The vertical displacement is approximately 2,000 feet below the block southwest of the graben (figs. 25 and 26) and 1,200 feet below the block northeast of the graben (fig. 27). The graben dies out southeastward at the Terlingua monocline and northward a short distance outside the Terlingua district. In places, the areas adjacent to the graben are "sagged" toward it in such a way that fault displacement is lessened. The overall trend of the bounding faults is N. 70° W. in the southern part of the graben, N. 30° W. in the central part, and N. 20° W. in the northern part. Part of the difference in trend is attributable to an echelon arrangement of faults such that the overall trend of the fault zone differs from that of the individual fault planes. There is a noticeable tendency toward parallelism of the individual, component fault planes with the regional fracture pattern. For instance, the most prominent directions of fracture immediately west of the northern part of the graben are N. 85° E., N. 65° E., N. 20° W., and N. 45° W. (fig. 12); and the graben faults locally follow each of these trends except the first. West of the Rainbow mine the graben faults on the northern side follow a trend of N. 65° E. to N. 80° E. for half a mile, thus causing a widening of the graben in this area.

Black Mesa graben zone

The discontinuous group of grabens having an overall trend of N. 75° E. and extending from west of Black Mesa almost to Long Draw is herein called the Black Mesa graben zone. Although its characteristics are diverse,

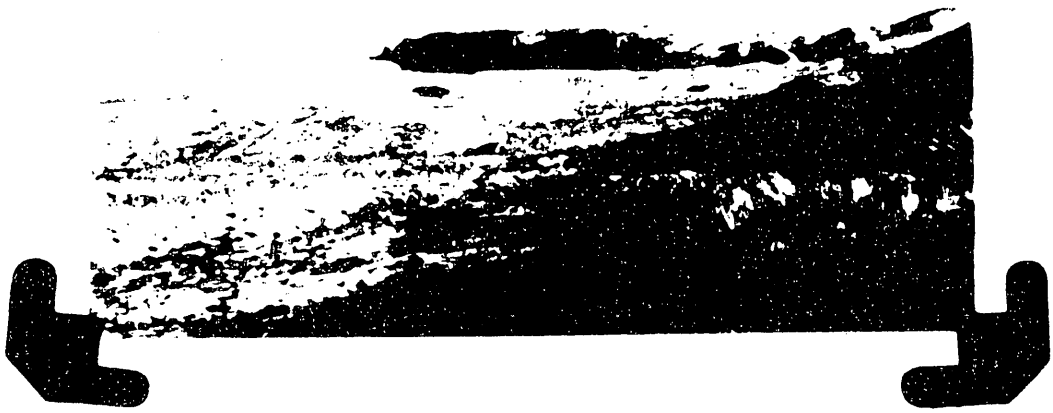

Figure 26.—The southwestern fault of the [illegible] graben at Reed Plateau. Boquillas flags, in the foreground and at the lower left, are faulted against Devils River limestone in the cliff.

[illegible]re 27.— [illegible]ult breccia [illegible] hill[illegible] [illegible]l[illegible] on [illegible]rtheastern [illegible]ult of the Long [illegible] graben. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] by caliche.

certain general differences from the Long Draw graben stand out. The unusual northeast trend has already been mentioned. Further, the graben zone is not so long nor so continuous as the Long Draw graben; the fault displacements are generally less, and there is no marked difference between the displacements on the two sides, as there is in the Long Draw graben. The northeastern part of the zone, near Long Draw, is fairly typical of the Terlingua grabens, whereas the Lowes Valley part, adjacent to Black Mesa, is a chaotic jumble of faulted blocks, lacking the relatively straight, linear boundaries of the usual graben.

The northeastern part of the Black Mesa graben zone contains Grayson formation and Buda limestone faulted into Devils River limestone, with a maximum vertical displacement of approximately 400 feet. The graben block is synclinal with an axial strike of N. 55° W. across the N. 65° E. strike of the graben; this explains why the graben faults die out in both directions away from the syncline. Near the axis of the syncline is a breccia pipe containing fragments of Buda limestone and Boquillas flags enclosed in the Grayson formation. Immediately southeast of this part of the graben zone a square prism is tilted southwestward, with faults on all four sides. Two of these faults intersect the graben faults without noticeable offset. Buda limestone and Grayson formation are preserved in the structurally lowest part of the tilted block, along the southwestern fault, which has a displacement locally in excess of 200 feet. Between the northeastern part of the graben zone and the Lowes Valley graben, the faults die out; but farther southwest, on the flank of the Black Mesa dome, the fault zone reappears. Here the faults are relatively insignificant in displacement, but still farther southwest at Lowes Valley the displacements are large.

The Lowes Valley graben is not confined to the same narrow width as the rest of the graben zone, and it is probably complicated by a later structure superimposed on the graben. Large areas of alluvium and poor exposures at the contacts make age relations and the exact outline of the structure uncertain.

The Lowes Valley graben is partly separated into an eastern and a western half by a ridge of Devils River limestone extending two-thirds of the way across the graben. The eastern half is an irregular, roughly circular area that contains pyroclastic rocks and conglomerate correlated with those of the Chisos volcanics, and also a small outcrop of Boquillas flags, which is tentatively, but inconclusively, correlated on lithologic grounds with the lower member of Boquillas flags. A minimum vertical displacement of at least 800 feet is represented by this outcrop.

The presence of the Chisos volcanics suggests at least three possible interpretations of the origin of this part of the graben. The first hypothesis is that the Chisos volcanics unconformably overlie the Boquillas flags and were faulted into the graben along with the flags. This is in agreement with unconformable relations between Chisos volcanics and Boquillas flags found further west. A second hypothesis is that the Chisos volcanics were deposited in a structural and topographic depression, likewise in unconformable relation with the Boquillas flags, but after the faulting. Because the contacts between Chisos volcanics and bounding rocks of the graben are not well enough exposed to prove the faulting necessary for the first hypothesis, the second hypothesis must be considered. A third hypothesis, that the area is a volcanic vent choked with its own debris, is untenable because of the content of bedded stream gravels typical of the interbedded gravels of the Chisos volcanics.

Even if the second hypothesis is correct and the volcanic rocks accumulated in a depression, there is evidence of postvolcanic displacement of the graben. The bedding of the pyroclastic rocks is locally steeper than the angle of repose for unconsolidated material of similar composition, thus indicating at least an inward sagging of the volcanic rocks after their deposition. If the rhyolite, shown on plate 1 as of questionable intrusive origin, is assumed, on the contrary, to be of extrusive origin, it then lends some support to the idea of postvolcanic faulting, because the 60° platy parting may then represent a tilt of this magnitude from an original horizontal or near-horizontal position. On the other hand, if the rhyolite is intrusive, the platy parting suggests that the intrusion may be sill-like into deformed pyroclastic rocks. No matter which hypothesis of origin is accepted, the structure of the eastern half of the Lowes Valley graben must have been caused primarily by downfaulting.

The western half of the Lowes Valley structure is a more nearly typical graben except that the rocks are highly broken. Grayson formation, Buda limestone, and Boquillas flags floor the exposed portion of this area. The displacement of the Boquillas flags is at least 1,100 feet downward relative to the surrounding area. Southwestward in the graben, the rocks are all Devils River limestone and are displaced no more than 500 feet on the graben faults. This change in displacement is so abrupt that a cross-fault in the floor of the graben beneath the alluvium is required to explain it.

It has been shown that the Lowes Valley graben structure must have been caused primarily by downfaulting. Yet it is distinguished from the rest of the Black Mesa graben zone by its peculiar outlines, its large

displacement, and the fact that its rocks are broken. The larger problem of origin centers upon how space was provided for the downfaulted rocks, and two answers that might be suggested are (1) solution of large quantities of limestone, and (2) withdrawal of magma. If the first answer is correct, the structure is similar in origin to the breccia pipes, discussed on a subsequent page. If the second answer is the correct one, the structure is comparable with cryptovolcanic structures in other regions. Of them Williams 24/ says, "Where the evidence is clear, the cryptovolcanic disturbances begin with an upwarping or a bysmalithic up-punching of the crust." This process is certainly represented by the laccolithic or bysmalithic dome of Black Mesa. Williams continues, "---finally, in part owing to loss of gas from the magma and in part to contraction of the magma on cooling or an actual withdrawal of magma, subsidence occurs."

Well Creek grabens

Well Creek drains three adjacent valleys west of Long Draw and north of the Mariposa mine, each of which is graded in a graben block wherein Grayson formation and Bain limestone are faulted into the Devils River limestone. The pattern of overlapping, convergent, and angular faults bounding these three grabens is best grasped by reference to plate 1. The displacement on the bounding faults (fig. 28) is not more than 500 feet and generally is only about 250 feet. Where the graben faults die out, it is common for monoclinal rolls to take their places; these rolls become lower and lower until they too finally disappear. On the other hand, some of the graben faults end abruptly, with the displacement taken up on a terminal cross fault or fold; note the hooklike northeastern end of the

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24/ Williams, Howel, Calderas and their origins Univ. of Calif. Bull. of Dept. of Geol. Sciences, vol. 25, no. 6, p. 300, 1941.

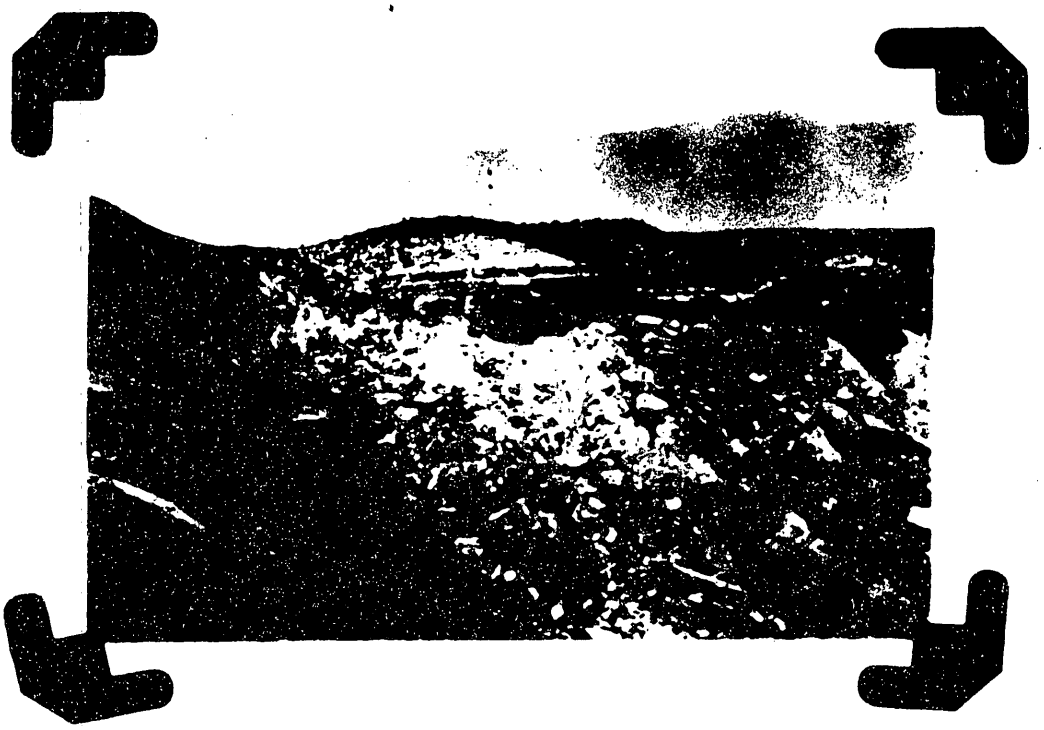

Figure 28.--The westernmost fault of the [illegible] grabens, near Black Mesa. Light-colored [illegible] limestone on the right is faulted against dark colored Devils River limestone on the left.

graben adjacent to the Waldron mine. In summary, the Well Creek grabens differ from the Long Draw graben in their size and displacement and the fact that the blocks east and west of the grabens are not relatively displaced as at Long Draw. Otherwise the structural affinities between the Long Draw and Well Creek grabens are close.

Cigar Mountain graben

Striking southeastward from Cigar Mountain is one of the larger grabens of the Terlingua district. It has a length of about three miles, a width of one mile, and a vertical displacement of 1,000 to 2,000 feet, decreasing near the southeast and northwest ends of the graben. In addition, the trend is continued in the faulted, structurally low area extending northwestward from Cigar Mountain. The mountain itself is composed of igneous rock intruded sill-like into the floor of the graben after the faulting. The southwestern fault may have served as one of the feeding channels for the intrusion, which protrudes southeastward as a narrow dike for a short distance along the fault. Between the bounding faults of the graben, the rocks are Terlingua clay and Aguja sedimentary rocks, but alluvium conceals most of the area.

Other structural depressions

Structural depressions other than grabens are common. They are especially well marked in the northwestern part of the district because of the striking lithologic differences of the rocks. Many of these structures are saucer-shaped depressions, or irregular downfaulted blocks without a dominant long dimension such as the grabens have. They differ also from

breccia pipes, which are composed of broken-up, intermixed rocks that have been displaced downward for a much greater distance relative to the width of the structure. Possibly there is no sharp distinction between structural depressions and breccia pipes; the larger breccia pipes, especially in areas of poor exposures, may be equivalent to what were mapped as structural depressions in other areas. The breccia pipes present such an interesting and individual problem, however, that they are discussed in a separate subsequent section.

Fresno mine area

The Fresno mine area is in both a structural and topographic depression. The Grayson formation and younger rocks form the floor of the depression, which is bounded on three sides by the topographically higher, but stratigraphically lower, Devils River limestone. On its fourth side, the depression is ill-defined, dying out as the Terlingua monocline is approached. The contact of the Grayson with the underlying limestone is in some places a normal contact but in many places cuts across the bedding of the limestone. Exploration below some of these discordant contacts has shown that they are underlain by undisturbed, flat-lying or gently dipping Devils River limestone; thus the conclusion is warranted that such contacts are either depositional unconformities or are solution features caused by removal of limestone and consequent lowering of the Grayson formation. The detailed evidence from the surface and from the mine workings is overwhelmingly in favor of the latter conclusion. The nature of the contacts is illustrated in figures 38, 39, and 40. The large number of breccia pipes in the Fresno area is a further indication of the importance of limestone solution

in forming the Fresno structural depression. Several iron-stained and silicified areas of Devils River limestone suggest hydrothermal waters as the agent of solution.

Two structural depressions east of the Fresno mine warrant mention. The first, approximately 1½ miles eastward, is nearly half a mile in diameter and contains a block of Grayson formation and Buda limestone. The outer contacts are covered by alluvium. This structure could have originated only by vertical movement, such as would be caused by local removal of support from below; that is, local removal of magma or of limestone in solution. The latter is more probable, considering the great amount of solution that has taken place in the bordering limestone and the fact that breccia pipes due to solution are localized in this area. The second structural depression is approximately half a mile southwest of the first and just east of the Presidio-Brewster county line. It is much smaller than the first and contains only the Grayson, but in origin it appears to be similar.

Mariposa mine area

The Mariposa mine area is a structural depression bounded on the south by the crescent-shaped Duncan fault and on the north by beds of gentle south dip and by smaller faults. Displacement on the Duncan fault dies out both eastward and westward. A great amount of solution has occurred in the uppermost beds of the Devils River limestone. Solution features are concentrated along the northeast trending fractures and fade outward from them into the closely spaced bedding planes of the upper part of the Devils

River limestone. Each bed is thinner near the fractures because of solution and therefore sags or dips toward the fracture (figs. 38 and 39). In the Mariposa area, like in other depression areas, there are numerous breccia pipes, and intrusions also are present. It is probable that there has been some solution of limestone over the whole Mariposa area and that this solution, as well as the faulting, is responsible for the depression.

Reed Plateau syncline

The wide faulted syncline on the northwestern side of Reed Plateau (fig. 25) trends N. 75° E. It merges into the Terlingua monocline southwestward, and is truncated by the Long Draw graben in the opposite direction. Several breccia pipes and two small igneous intrusions crop out within the synclinal area. It may be significant that the structural trend of the syncline is continued in fault trends on the northeast side of the Long Draw graben. In the graben itself, an intrusion and a large breccia pipe suggest that the structural trend carries through. These continuations suggest that the syncline may be the local expression of a more continuous structure at depth, which is reflected in the northeast trending center of the monocline southeast of Mariposa, the syncline, the intrusion and breccia pipe of Long Draw, the northeast trending faults in the vicinity of the Rainbow mine, and perhaps the Cigar Mountain intrusion.

Faults and fractures

The majority of the faults, fractures 25/ and joints in the Terlingua district belong to one of two sets, a northeastward set and a northwestward

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25/ The term fracture is used for breaks on which there is no measurable displacement but which are more persistent that typical joints. Some of these fractures can be traced in the field for half a mile or more.

set; although these sets vary considerably in strike, their intersections are commonly at nearly right angles. The northwestward set includes most of the major faults, the main exception being the northeast trending Black Mesa graben zone. All the major faults are normal faults, and most of them bound grabens. Among the smaller faults and the fractures, the northeast trending ones are the most persistent and prominent, whereas the northwest trending ones, exclusive of the graben faults of large displacement, tend to be less well developed and shorter (fig. 12). The great majority of all the faults and fractures have steep dips (60° to 90°).

Fault- and fracture-intersections show offsets of either set by the other and mutual offsets; they thus reveal no evidence tending to establish clearly separate ages for the northeastward and northwestward sets. Many of the faults and fractures, particularly those of northeast trend, show good evidence of oft-repeated small movements. That is, nearly all are mineralized by calcite, and alternate mineralization and movement resulted in the interleaving of calcite with thin sheets of country rock (fig. 29). Although the movement on the two sets was in part simultaneous or overlapping, movement on the northeast trending set probably continued longer than on the northwest trending set. This fact is suggested by the near restriction of late mineralization to the northeast trending faults and fractures.

The movement on the large normal faults was predominantly dip-slip, as evidenced by the lack of large horizontal displacement at fault intersections. However, no way was found to detect and accurately measure small

Figure [illegible].—[illegible] vein filling [illegible] the [illegible] level of the [illegible]. [illegible] slivers of country rock ([illegible] and [illegible]) in the vein were produced by repeated movement of the fault and repeated deposition of calcite.

horizontal displacements. That some horizontal movement took place is indicated by horizontal or gently inclined grooves, which are most common on the small faults but are found also on the large graben faults. Great grooves and striations of low dip on the graben faults near the southeastern end of Long Draw are good examples.

Horizontal grooves are more common than steep grooves on the northeast trending minor faults, and the lack of vertical offset on faults that show clear evidence of motion (brecciation, gouge, crumpling of beds) proves horizontal movement (fig. 30).

Concealed igneous intrusions have caused some of the faults and modified others, so that the displacements measured at the surface are accurate for the surface only. At depth below an intrusion there may be no fault or a fault of different displacement.

In the southwestern part of the Terlingua district, south of the Terlingua monocline and west of the southeastern end of Long Draw, there are many small faults splitting and crossing in a complex pattern, in contrast to the simpler fault pattern north of the monocline. Much of the difference is attributable simply to the different rocks exposed in the two areas. Faults that are single planes in the thick-bedded Devils River limestone become multiple splits in the less homogeneous rocks above the Devils River limestone. This significant difference tends to be magnified in mapping, however, because small faults are harder to detect in the relatively massive limestone. The northwest trending faults and perhaps the minor folds south and southwest of Tres Cuevas Mountain appear to be the dying-out expression of the great Santa Helena Canyon fault south of the

Figure 30.—Bulbous calcite vein in a fracture showing strike-slip movement. The vein and fracture end on a bedding plane above the 12-inch scale, the displacement being taken up by bedding plane slippage.

Terlingua district. Here as elsewhere in the district, the Terlingua monocline is a relatively unfaulted dividing line between the northwest trending faults north of it and those south of it. In the midst of the zone of normal faults southwest of Reed Plateau is a low-angle thrust fault dipping east; it is apparently offset by one of the normal faults.

In the eastern part of the Terlingua district, east of Long Draw, there is considerable local variation in the amount of deformation, but here again, the fault pattern tends to be most complex in the rocks of greatest heterogeneity.

Breccia pipes

For mapping purposes, masses of breccia with a pipelike or chimney-like shape have been designated descriptively as breccia-filled pipes, or simply breccia pipes, and are shown on plate 1 by blacked-in or cross-hatched areas. The fact that the breccia is displaced vertically downward in all the pipes indicates that they formed as a result of solution in the Devils River limestone and collapse-stoping of overlying strata. The dissolving agent is believed to have been hydrothermal solutions, but meteoric water is a possible alternative. Intrusion of magma into some of the breccia pipes occurred during or after their formation, and this fact suggests a possible mechanism for the emplacement of small plugs like or neckline intrusive bodies: namely, hydrothermal dissolving and collapse-stoping of a channelway, followed by intrusion. Breccia bodies similar in form have elsewhere been called diatremes or sinkholes according to the current idea of their origin. The characteristics of the breccia pipes can best be illustrated by describing in some detail several typical ones that are better

understood because they could be studied in mine workings or good surface exposures.

Four breccia pipes are described in detail: (1) Maggie Sink pipe, in Devils River limestone, 1 3/4 miles west of Mariposa; (2) Two-Forty-Eight pipe in Boquillas flags, at the Two-Forty-Eight mine; (3) Aguja pipe in Boquillas flags, on the Chisos mine property; and (4) Chisos pipe in the Grayson formation and Pule limestone, in the Chisos mine. As the vertical dimension of the pipes is the longest and the least well exposed, it is only by piecing together the information on all the pipes, obtained in the few mine workings and at the surface, that a composite picture can be constructed.

Maggie Sink pipe

Maggie Sink breccia pipe is in Devils River limestone about half a mile northwest of Tres Cuevas. It is in a topographic depression on the crest of an asymmetric anticline. Exploration for quicksilver mineralization to a depth of about 600 feet has provided considerable data about the structure. The pipe is roughly elliptical in outcrop; the outcrop has a length of 540 feet and a width of 200 feet (fig. 36); the long dimension is oblique to the axial trend of the anticline. Fractures and small faults, many filled with calcite, are numerous in the surrounding Devils River limestone, as they are throughout the Terlingua district, but significant intersections or concentrations of fractures that might account for the localization of the structure are absent.

The vertical or nearly vertical walls of the pipe, which are solution-pitted and coated by coarsely crystalline calcite, enclose a collapsed brecciated mass of Grayson formation, Buda limestone and Boquillas flags (figs. 31, 32, and 33). The Grayson, the most abundant constituent at the surface, occurs as a matrix for blocks of the other formations and for blocks of the harder Grayson strata. Much of the Grayson formation is plastic when moist and could easily have flowed under a gravitational load to form such a matrix. The Buda and Boquillas rocks are present as randomly oriented fragments ranging in diameter from less than an inch to several feet. Some blocks of Devils River limestone are present, especially near the borders of the pipe, and a few fragments lithologically similar to Chisos volcanics were found on the surface at the southeastern corner of the subwap.

Between 1943 and 1946 a tunnel was extended to intersect the pipe approximately 150 feet below the surface, and from this tunnel a winze was sunk to explore several hundred feet deeper. At the tunnel level, the breccia consisted of the same rocks as at the surface, Boquillas flags as well as the older strata having collapsed to this depth. The winze was not accessible at the time of the last visit to the property (1946), but the engineer in charge, Mr. Ray Hammond, reported that the wall of the pipe maintained an overall vertical attitude to the bottom of the winze, more than 400 feet below the tunnel. It is reported also that no bottom to the breccia pipe was found and that the breccia contained Buda limestone to the depth explored.

Figure 31.— The Maggie Sink breccia pipe as exposed after removal of some of the breccia by power shovel. The cliff is the wall of the pipe, with Devils River limestone to the right of the cliff and breccia of younger rocks to the left.

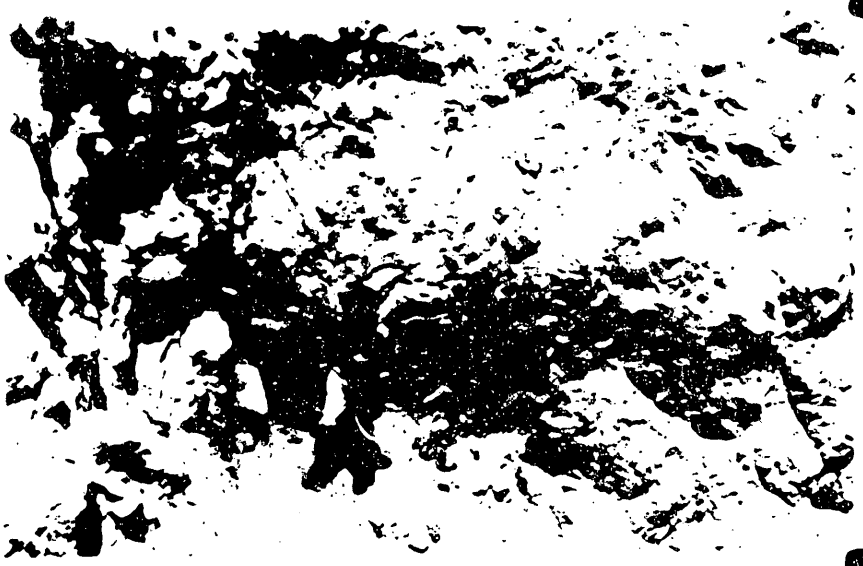

Figure 32.—Contact of the breccia at the southeastern side of Maggie Sink. Behind and to the right of the figure is brecciated Grayson formation, Buda limestone, and Boquillas flags; at the left is undisturbed Devils River limestone.

Figure 33.—Solution-pitted limestone wall of the Maggie Sink pipe, revealed after removal of the breccia in prospecting operations.

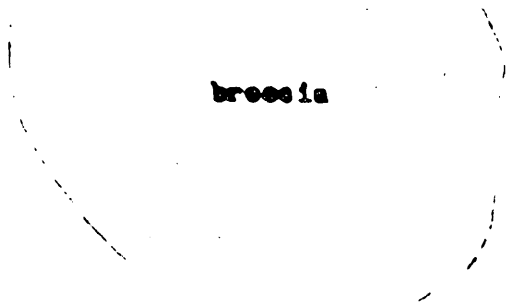

FIGURE 34
Outline map of Aguja breccia pipe, near the Chisos mine; scale 1 inch equals 100 feet. The surrounding rocks are Boquillas flags; the breccia is broken sandstone and clay of the Aguja formation, displaced downward an estimated minimum of 1500 feet.

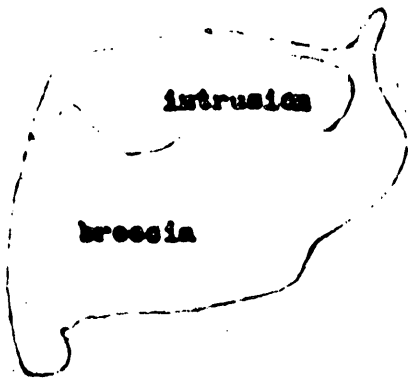

FIGURE 35
Outline map of breccia and intrusion south of the Aguja pipe; scale 1 inch equals 100 feet. The surrounding rocks are Boquillas flags; the breccia is broken Boquillas; and the intrusion is basaltic.

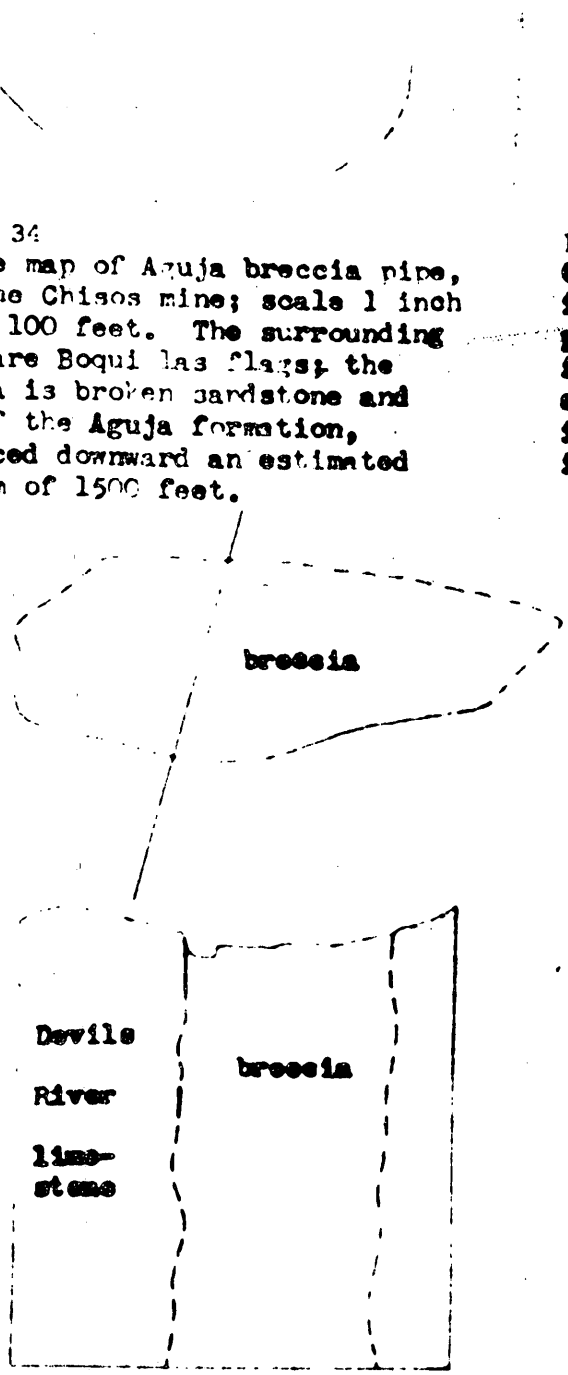

FIGURE 36
Outline map and vertical section of Maggie Sink breccia pipe; scale 1 inch equals 200 feet.

Line on outline map shows direction of section. The surrounding rock is Devils River limestone; the breccia is broken Grayson formation, Buda limestone, Boquillas flags, and possibly some Tertiary volcanic rocks. The breccia in the outcrop is displaced downward as much as 900 feet or more.

Altered rock is conspicuous along the walls. Surfaces that may have been formed originally by caving off of Devils River limestone during formation of the breccia pipe are now pitted, rounded, and coated with calcite, some of which contains cinnabar (fig. 33). The breccia near the walls and locally within the pipe is bleached and iron-stained, the Grayson formation and Boquillas flags having been affected most, whereas the Buda limestone is unaltered. The surfaces of the fragments are generally sharp clean breaks and are only locally modified by solution.

Maggie Sink pipe, in summary, is a breccia mass of unknown depth, with nearly vertical walls extending at least 600 feet below the top of the Devils River limestone. It is filled with collapsed breccia of rocks usually overlying the Devils River limestone. Some of the breccia has moved downward at least 500 feet and probably considerably more. Quicksilver mineralization affords proof of hydrothermal activity.

Two-Forty-Eight pipe

The breccia pipe explored by the Two-Forty-Eight mine is on the western side of the broad, low Two-Forty-Eight dome. The upper member of Boquillas flags in the vicinity dips gently westward at angles of less than 10° and is unbroken except for the breccia pipe and fractures of less-than-a-foot displacement trending N. 65° E. and N. 20° W. These fractures belong to the regional system of northeast and northwest fractures, which are only weakly developed here. The Cigar Mountain laccolithic intrusion is only three-quarters of a mile to the northwest, and the large graben of the same name is within a quarter of a mile to the west.

The breccia pipe is more thoroughly explored for a greater vertical distance than any other in the district. From a mine shaft more than 600 feet deep, exploratory workings at vertical intervals averaging 50 feet are driven on the contact of the breccia. Near the surface, the pipe is nearly circular in cross-section and has a diameter of 115 feet; it enlarges to an elliptical cross-section with a maximum dimension, in a northerly direction, of about 200 feet on the 400 level (fig. 37). The breccia consists of Boquillas flags on the upper levels and intermixed Boquillas and Buda rocks below the level where the Buda surrounds the pipe. One block, seen on the 556 level, contains the Buda and Boquillas contact and has been displaced 25 feet downward. The breccia is much like that in a caved mine stope, consisting of blocks and fragments of all sizes, oriented randomly. The contact between breccia and enclosing country-rock is sharp. There are blocks in all stages of detachment and slump, and without exception they show downward movement. The wall rocks are not dragged or bent at the contact, which indicates that the pipe formed by caving block-by-block. Much of the breccia has a matrix of the softer shaly parts of the Boquillas flags, but some of it has open space with no matrix. In many places, calcite, hydrocarbons, and analcite 26/ are present. Locally, hydrocarbons were abundant enough in the quicksilver ore to provide the fuel for furnacing, and in some places were so abundant that they caused considerable trouble in the furnacing.

26/ Milton, C. M., A foraminiferal analcite shale from Texas (abstract), Washington Acad. Sci. Jour., vol. 26, p. 386, 1936.

A post-breccia sill surrounds the pipe on the 500-foot level, having lifted the wall rocks without lifting the breccia. It fingers into the breccia and bakes the breccia along the contact. Altered, but probably similar, igneous rock is intruded into the breccia explored by the main shaft below the 556-foot level. Calcite and cinnabar occur in veinlets in the igneous rock, thus revealing a history of fracturing and mineralization subsequent to the intrusion.

Some of the breccia fragments are softened and bleached, and here, as at Maggie Sink, the shale is affected much more than the limestone. The igneous rock also is altered, and in places is completely changed to clay. The alteration of the igneous rock is most intense along the border of the pipe. Warm water, hydrogen sulfide, and possibly other gases, which were combustible, were present in newly opened parts of the mine but disappeared after a few days.

The breccia in the Two-Forty-Eight pipe is similar to the breccia in the Maggie Sink pipe, and the direction of displacement is the same. The overall form of the two pipes also is similar, although the circular outline of the Two-Forty-Eight pipe at the surface is in considerable contrast to the marked elliptical outline of the Maggie Sink pipe. The Two-Forty-Eight pipe changes to an elliptical outline at depth, and this outline suggests that the wall rocks exerted some control over the shape and that the pipes have very similar shapes in the Devils River limestone. Further, it is reasonable to assume that the walls of the lower part of the Two-Forty-Eight pipe, in Devils River limestone, are rounded by solution rather than being angular in detail like the upper part; the part

of the pipe in this limestone has not yet been explored, however. The principal geologic difference between the two pipes is the presence of the igneous intrusion at Two-Forty-Eight. This intrusion may account for part of the alteration, and certainly it is partly responsible for the structure itself, because lifting of the beds above the 500-foot level increased the displacement of the brecciated rocks from their normal stratigraphic positions and must have activated an upward extension of the pipe.

In brief summary, the geologic history of the Two-Forty-Eight breccia pipe is: (1) formation of a collapse breccia owing to removal of material at depth; (2) sill-like igneous intrusion into the surrounding strata and into the breccia itself; and (3) further minor faulting and mineralization by calcite and cinnabar.

Aguja pipe

On the Chisos mine property 1,500 feet east of the main or No. 8 shaft is the Aguja breccia pipe in the trough of a syncline. The syncline has an axial trend of N. 23° E., maximum dips of 30°, and a southwestward plunge. The rocks outside of the pipe are the upper member of Boquillas flags, whereas the breccia within the pipe is sandstone and clay of the Aguja formation. Numerous calcite veins filling fractures and faults of the regional northwestward and northeastward systems traverse this general area, and one northeast trending vein, explored in the shallow Susano prospect shaft, cuts the breccia.

The outcrop of the pipe covers a roughly circular area 250 feet in diameter (fig. 34). The walls are approximately vertical where exposed and where explored by drill holes. Within the pipe is a jumbled mass of the Aguja formation consisting of sandstone in a matrix of clay; some of the sandstone blocks are very large; up to tens of feet in diameter. As the Aguja formation normally overlies about 1,200 feet of Terlingua clay, which rests upon Boquillas flags, the presence of Aguja rocks in a pipe surrounded by the upper member of Boquillas flags indicates a very large displacement. The probable displacement is estimated to be more than 1,500 feet. This figure may be too high, as it depends upon the thickness of the Terlingua clay, no section of which is exposed nearby; but the displacement must be at least 1,000 feet. The known geologic history of the Aguja breccia pipe includes: (1) formation of the breccia by collapse, and (2) repeated movement accompanied by calcite mineralization and ending with cinnabar mineralization on at least one fracture.

Another breccia mass crops out 800 feet south of the Aguja pipe. It is enclosed in Boquillas flags, consists of fragments of the same formation, and contains an intrusion of basalt. A drill hole between the two breccia bodies, but closer to the Aguja pipe, passed through a seven-foot sill of similar basalt at the lower Boquillas contact 852 feet below the surface. The best interpretation of the second breccia mass appears to be that, like the Two-Forty-Eight pipe, it is a breccia pipe formed by collapse and later intruded by igneous rock. Lack of exploratory workings and good exposures of the walls, however, makes this conclusion uncertain.

Chisos mine pipe

The most famous of the Terlingua breccia pipes is the Chisos pipe in the Chisos mine, because from it was mined the largest and most valuable single ore body in the district. This pipe does not reach the surface but was discovered in mine workings at a depth of 550 feet and was mined and explored an additional 250 feet downward. It is tangent to the Chisos fault in an area where this fault frays out into a number of calcite veins along fractures with little displacement. There appears to have been minor movement along the Chisos fault after formation of the breccia. Above the breccia pipe are flat-lying Boquillas flags, undisturbed except by the Chisos fault. Below its roughly-arched roof of Boquillas flags, the pipe is surrounded by near-vertical walls of Buda limestone and below that by the Grayson formation; information regarding the walls at greater depths is lacking.

The pipe, which is roughly circular with a diameter of about 75 feet, is filled by breccia of the Grayson formation, Buda limestone and Boquillas flags, all displaced downward. The upper part of the pipe, now mined out, is reported to have been a breccia of Boquillas flags and Buda limestone with interstices filled with calcite and cinnabar. The lower part of the pipe, also mineralized in places, is mainly a breccia of Buda limestone in a matrix of Grayson. [illegible] warm, unmineralized water was found on lower levels in this part of the mine, and was pumped to the surface for use as drinking water.

Thus the Chisos pipe is a vertical breccia-filled cylinder in which the fragments have collapsed to their present position. As the overlying rocks are undisturbed, the indicated theory of origin is removal of material, probably from the Devils River limestone, and contemporaneous

collapse-stoping upward until the volume increase consequent upon brecciation filled the structure and supported its roof.

To get an idea of the volume relations, let us assume that the removed material was taken from the top strata of the Devils River limestone 300 feet below the top of the pipe and that brecciation of the overlying column of Cruyeen and Buda rocks involved an expansion in volume of 30 percent. It can then be concluded that a volume of Devils River limestone equal to a cylinder having the diameter of the pipe and a height of 90 feet (30 percent of 300 feet) must have been removed. Taking a diameter of 75 feet, this would be a volume of 400,000 cubic feet in round numbers. Let us further assume that the limestone was dissolved, carried out through the wall rocks, and all of it deposited as calcite veins. The volume is sufficient to form six veins averaging four inches thick, 500 feet long, and 400 feet deep. The actual volume of vein calcite in the mine area is far greater than this.

A number of igneous intrusions, mostly sills and dikes, were found in parts of the Chisos mine workings. Immediately above one of them, the Boquillas flags are brecciated by the intrusion. The breccia mass differs from the breccia pipes in several respects, namely, its small vertical extent, irregular shape, gradational walls, and nature of the breccia. The breccia is crumpled, thrust, squeezed, and uplifted; it is composed of Boquillas rocks with no intermixture of rocks from other formations. This rock is more distorted than brecciated; in contrast, the breccia of the Chisos pipe, which is typically in discrete blocks (except for the soft clays), is not folded or thrust, it is displaced downward, and it is

composed of a mixture of rocks from different formations. In short, the breccia of the pipe has a striking resemblance to caved material in an old mine stope, whereas the intrusion breccia shows every evidence of having been formed by local, forceful shouldering aside.

Other breccia pipes in the Terlingua district

A total of 76 breccia pipes are shown on the areal map, plate 1, and their geology is summarized in table 1 below. They appear in outcrop as a mixed jumble of rock fragments from different strata. Some form small conical hills or low mounds because the breccia is more resistant to erosion than are the surrounding rocks, whereas at the other extreme, some form depressions because they are less resistant than the surrounding rocks. They commonly have a roughly circular or roughly elliptical outcrop, with a preferred northeastward elongation; however some are too irregular to be thus described. The oldest rock in which the breccia pipes are found is the oldest rock exposed in the district, the Devils River limestone. The youngest rock in which they have been found is Terlingua clay; however, the breccia filling includes the Chisos volcanics, the youngest rocks exclusive of Quaternary gravels in the district. Thus they crop out not only in Devils River limestone where they are directly associated with solution features but also in younger rocks where only mechanical collapse—with no solution—is apparent. The Devils River limestone is the only thick limestone formation in the section. It is consistent with all the known facts to conclude that the pipes cropping out in rocks younger than Devils River limestone are

Table 1.—Breccia pipes shown on plate 1.

The breccia pipes are listed in order from west to east. Symbols: Kd, Devils River limestone; Kg, Grayson formation; Kbu, Buda limestone; Klb, lower member of Boquillas flags; Kub, upper member of Boquillas flags; Kbo, undifferentiated upper and lower members of Boquillas flags; Kt, Terlingua clay; Ka, Aguja formation; Tv, Tertiary volcanic rock and conglomerate.

	Location and comment	Surrounding rock at the surface	Observed composition of breccia at the surface	Estimated minimum displacement of fragments of youngest rock in the breccia at the surface (feet)
1.	W. of Freeno	Klb	—	—
2.	W. of Freeno, in plunging syncline	Klb	—	—
3.	NW. of Freeno	Kg-Kbu	Kbu	50
4.	Freeno area	Kbu	Kbo	50
5.	NW. of Freeno	Kdv	Kg,Kbu,Kbo	300
6.	Freeno area	Kbu	Kbo	100
7.	Freeno area	Kbu	—	—
8.	Freeno area	Kdv-Kg	Kbo	300
9.	Freeno area	Kg-Kbu	Kbo	100
10.	Freeno area	Kg	Kbu,Kbo	150
11.	Freeno area	Kg	Kbu	50
12.	Freeno area	Kg	Kbu,Kbo,Tv	400
13.	Freeno area	Kg	Kbu,Kbo,Tv	400
14.	Freeno area	Kg	Kbu,Kbo	200
15.	Freeno area	Kdv	Kbu,Kbo,Tv	450
16.	Freeno area	Kg	Kbu,Kbo,Tv	300
17.	Freeno area	Kdv	Kg,Kbu,Kbo,Tv	450
18.	S. of Freeno area	Kg	—	—
19.	Freeno area	Kdv	Kg,Kbu,Kbo	300
20.	Freeno area	Kg	—	—
21.	County line	Kdv	—	—
22.	County line	Kdv	—	—
23.	In structural depression	Kdv	Kg,Kbu,Kbo	[illegible]
24.	In structural depression	Kg	Kbo	200
25.	In structural depression	Kdv-Kg	Kbo	300
26.	In structural depression	Kdv	Kg	50
27.	Monocline at intrusion	Kdv	Kg,Kbu	200
28.	N. of monocline	Kdv	Kg,Kbu,Kbo	350
29.	N. of monocline	Kdv	Kg,Kbu	200
30.	Monocline	Kdv-Kg	—	—
31.	Downfaulted syncline	Kg-Kbu	Kbo	100
32.	Downfaulted syncline	Kdv-Kg	Kbo	250

Table 1.—Breccia pipes shown on plate 1 (continued).

	Location and comment	Surrounding rock at the surface	Observed composition of breccia at the surface	Estimated minimum displacement of fragments of youngest rock in the breccia at the surface (feet)
33.	S. of monocline	Klb	Khe	—
34.	Downfaulted synoline	Kg-Khu	Khu,Khe	100
35.	N. of Lowes Valley	Kdv	Kg,Khu	200
36.	Lowes Valley	Kdv	Kg,Khu,Khe	300
37.	S. of Lowes Valley	Kdv	Kg,Khe	300
38.	S. of Lowes Valley	Kdv	Khu,Khe	300
39.	S. of Lowes Valley	Kdv	Khe	300
40.	Maggie Sink, on an anticline	Kdv	Kg,Khu,Khe,Tv?	300
41.	S. of Lowes Valley	Kdv	[illegible]	—
42.	Monocline	Kg	—	—
43.	Mariposa, intruded by igneous rock	Kdv	Khu,Khe	300
44.	N. of Lowes Valley	Kg	Khu,Khe	100
45.	Mariposa, intruded by igneous rock	Kg	Khu,Khe	100
46.	Mariposa, intruded by igneous rock	Kg-Khu	Khu,Khe	100
47.	Mariposa area	Kdv-Kg	Khu,Khe	300
48.	SE. of Mariposa	Kdv	Kg	50
49.	Mariposa area	Kdv-Kg	Khu,Khe	300
50.	SE. of Mariposa	Kdv	Kg,Khu	200
51.	SE. of Mariposa	Kdv	Kg,Khu	200
52.	SE. of Mariposa	Kdv	Kg,Khu	200
53.	SE. of Mariposa	Kdv	Kg,[illegible]	[illegible]
54.	SE. of Mariposa	Kdv	Kg,Khu	200
55.	SE. of Mariposa	Kdv	Kg,Khu	200
56.	SE. of Mariposa	Kdv	Kg,Khu	200
57.	SE. of Mariposa	Kdv	Kg,Khu	200
58.	Mariposa road, intruded by igneous rock	Kdv,Kg	Khu,Khe	300
59.	AA monocline	Khu	Khe	50
60.	NW. of Waldron mine	Kdv-Khu	Khu,Khe	100
61.	W. of Waldron mine	Khu	Khe	50
62.	SE. of Waldron mine	Kg	Khu,Khe	150
63.	SW. of Little Thirty-Eight mine	Kg	Khu,Khe	100
64.	SW. of Little Thirty-Eight mine	Kdv-Kg	Kg,Khu,Khe	300
65.	S. of Little Thirty-Eight mine	Khu	Khe	50

Table 1.—Breccia pipes shown on plate 1 (continued).

	Location and comment	Surrounding rock at the surface	Observed composition of breccia at the surface	Estimated minimum displacement of fragments of youngest rock in the breccia at the surface (feet)
66.	S. of Little Thirty-Eight mine	Kg-Kbu	Kg,Kbu,Kbo	100
67.	S. of Little Thirty-Eight mine	Kg	Kg,Kbu,Kbo	200
68.	SE. of Little Thirty-Eight mine	Kdv,Kg	Kbu,Kbo	250
69.	N. of Reed Plateau	Kdv	Kg,Kbu	200
70.	N. of Reed Plateau	Kg	Kg,Kbu	150
71.	N. of Reed Plateau	Kdv	Kg,Kbu	200
72.	Long Draw, along graben fault	Kt	Kt,Ka,Tv	1000
73.	Aguja pipe, Chisos mine area; in plunging syncline	Kub	Ka	1500
74.	Chisos mine area, intruded by igneous rock	Kub	Kbo	—
75.	Two-Forty-Eight mine, intruded by igneous rock	Kub	Kbo	25
76.	N. of Two-Forty-Eight mine	Kub	—	—

merely the upper parts of pipes that extend downward into the limestone, and this conclusion has been proved in some instances by mining or drilling. Thus a composite picture can be drawn of a breccia mass commonly having great vertical extent compared to its diameter; a cylinder with a height-to-diameter ratio of seven to one would represent the average proportions observed.

The bounding walls of the breccia, exposed in gullies and mine workings, are generally sharp and nearly vertical. They typically show no signs of drag, but locally show blocks that are partly slumped off the walls into the breccia. The breccia itself is composed of randomly oriented fragments from a fraction of an inch to tens of feet in diameter, and these fragments are displaced below their normal stratigraphic positions in every case. The amount of downward displacement, which can be measured most accurately where the lithologic units are thin, is up to many hundreds of feet.

The breccia pipes are commonly from 100 feet to 300 feet in diameter, but some are as small as 50 feet and some are much larger than 300 feet. The minimum diameter is probably a reflection of the strengths of the rocks, which, with the exception of the Grayson formation, are strong enough to arch over smaller spans. Smaller slump structures typically involve only the Grayson and are also sufficiently different in form to be discussed separately as cave-fill structures. It is not so easy to state an upper size limit, as the largest breccia pipes may be transitional to other structural depressions. For example, a broken-up area of Chinle volcanics a mile northwest of Bee Mountain is more than 500 feet in diameter, the

slumped area of Chisos volcanics in the Fresno area is 600 feet wide, and the Lones Valley structure is 4,000 feet wide. These larger structural depressions, because they are too large to have had competent roof arches, may have been let down more gradually and therefore more nearly as a unit, thus masking somewhat their kinship with breccia pipes.

The relation of igneous rocks to the breccia pipes is interesting. Tertiary extrusive rocks are older than the pipes in the six cases where relative ages were revealed by the presence of fragments of Chisos volcanics and conglomerates in the breccia. Probably all the pipes are contemporaneous with or younger than the Chisos volcanics. Tertiary intrusive igneous rocks, on the other hand, intrude at least five breccia pipes. The clarity of the evidence of later intrusion is striking in the Two-Forty-Eight pipe and also in some of the Mariposa pipes. In one of the latter, for example, the igneous rock is intruded as a matrix into a mixed jumble of Buda and Boquillas blocks on one side of the pipe. Around the intrusion is a halo of baked breccia and wall rock. Thus the collapse and intermixture of Buda and Boquillas blocks must have preceded the baking and therefore the intrusion. It is recognized that these evidences of relative age are strictly applicable only to one level, and that at a deeper level the age relations might be reversed.

The distribution of the breccia pipes (pl. 1) is not uniform, for the majority are in the area of Devils River limestone. The main reason for this circumstance is suggested most clearly by the conditions in the Chisos pipe. The top of this pipe is just above the Buda and Boquillas contact; therefore the pipe must have lost the power to stope upward when

it reached this height. Probably this condition was general when the pipes were formed; that is, solution and undermining occurring in the Devils River limestone 22/ caused collapse-stoping that ended upward in overlying formations. Though some of the breccia pipes may have reached the surface at the time of their formation, it is probable that the majority have been exposed only by subsequent erosion. Thus the known breccia pipes are most numerous in the area of Devils River limestone mainly because this is the area of deepest erosion. The difference in distribution is probably exaggerated, however, because the number of pipes that have not been discovered is probably greater in the Boquillas flags and rocks above, than in the Devils River limestone. The reason for this condition is that there are thin, contrasting stratigraphic units immediately above the Devils River limestone, and therefore pipes in it contain foreign rocks that make discovery of the pipes relatively easy; on the other hand, pipes in the higher horizons, where the stratigraphic units are thicker, are much less apt to have foreign rocks.

Origin of the breccia pipes

Process of undermining and collapse

The nature of the breccia and its walls indicates collapse due to undermining as the origin of the Terlingua pipes. Common features of the pipes that point to this process are the downward displacement of the fragments, the absence of drag or thrust structures, the presence of slump structures along the walls, and the vertical cylindrical form.

22/ Undermining in the thin Buda limestone has been relatively unimportant.

The process of undermining and collapse is familiar to mining engineers and geologists, in block-caving methods of mining, in the formation of sinkholes in limestone regions, and in subsidence over salt domes, to mention a few examples.

Block-caved areas resemble breccia pipes in size, in the nature of the filling and in the attitude of the walls. 28/ They vary in size, but a block 150 feet by 150 feet, by 200 feet high, is representative. Speaking of the wall of a block-caved stope, Gardner 29/ says that it may project slightly over the caved ore, stand vertically, or even project outward. The upward growth of a large block-caved stope may continue to the surface; Gardner 30/ states, "In mining large ore bodies by caving system of mining the surface is broken and subsides as the ore is drawn."

Sinkholes may be formed in areas underlain by limestone even though the limestone is buried under several hundred feet of noncalcareous rocks. Stockdale 31/ describes one such sinkhole on the Cumberland Plateau near Chattanooga, Tennessee. It is a sinkhole 300 feet in diameter with a lake 130 feet below the rim. The walls are of flat-lying sandstone, conglomerate, and shale; the underlying limestone is at a depth of more than 800 feet. Stockdale states, "The sinkhole resulted from collapse into a subterranean cavern, initiated in the soluble limestone 800 feet or more below." Lawrence 32/ describes a number of similar sinkholes on the Cumber-

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28/ Gardner, E. D., Undercut block-caving method of mining in western copper mines: U. S. Bur. Mines Inf. Cir. 6350, 1930.
29/ Idem., p. 11.
30/ Idem., p. 7.
31/ Stockdale, Paris B., Montlake—an amazing sinkhole: Jour. Geology, vol. 44, pp. 515-522, 1936.
32/ Lawrence, R. A., Sinkholes of the Cumberland Plateau: Jour. Geology, vol. 45, pp. 214-215, 1937.

land plateau developed in rocks 300 to 600 feet above the limestone.

Subsidence above the Sour Lake salt dome has been described by Sellards, 33/ who attributed it to the removal of solids, mostly salt, in connection with oil production. The Sour Lake sinkhole was probably 300 feet in diameter and 70 feet or more in depth when first formed; the depth to salt was 1,000 feet or more. Other familiar examples could be given of subsidence above oxidized sulfide ore bodies and above mined-out areas.

The Terlingua pipes must have formed by a mechanism similar to those that formed the above-described features. Once undermining had begun, slabs, bounded by bedding planes and joints, peeled from the roofs and piled up on the floors just as they are doing today in old stopes of the Chisos mine. When undermining was slower than caving, a cavity was filled and its roof temporarily supported owing to the volume increase accompanying brecciation. When undermining was relatively rapid, open space may have been maintained under the roof arch, which must have progressed upward faster in weak strata than in strong strata. In strong strata, a roof arch might hold until, by caving from the walls immediately beneath or by widening of the undermined area, the span was widened to the point of rupture. Such a process clearly is capable of producing the intermixed, down-dropped breccia in a vertical pipe and is indicated by all the evidence.

33/ Sellards, E. H., Subsidence in Gulf Coastal Plains salt domes: Texas Univ. Bull. no. 3001, Contributions to geology 1930, pp. 9-36.

Relation to cave-fill structures

Linear zones along which the Grayson formation is slumped into Devils River limestone are probably similar to the breccia pipes in origin.

These cave-fill zones (figs. 38, 39, and 40) generally occur along faults or fractures. They are typically hundreds of feet long and less than 50 feet wide, but the form and size are varied and complex, depending partly on the pattern of intersecting fractures. Their vertical dimension is usually less than 50 feet but in exceptional cases is several hundred feet. They are filled by more or less brecciated Grayson formation and Devils River limestone, the degree of brecciation being generally greatest near the bottom and grading upward into slumped, but not brecciated, beds. In the Grayson fifty feet or more above the top of the Devils River limestone, the cave-fill zones may be expressed as small synclines, and above the Grayson they are not likely to be expressed at all except above very large cave-fill zones.

The cave-fill zones, like the breccia pipes, are old features and are not known to be forming now. At the Mariposa mine, for example, cave-fill has been invaded by igneous rock, which used the fractures and mineralized by cinnabar. At numerous other places the cave-fill is ore. Thus the cave-fill zones, as well as the breccia pipes, are older than the cinnabar mineralization.

An explanation for the differences between the cave-fill zones and the breccia pipes may be found in their origin; the differences depend on the horizon at which undermining took place. A collapse structure caused by undermining some distance below the top of the Devils River

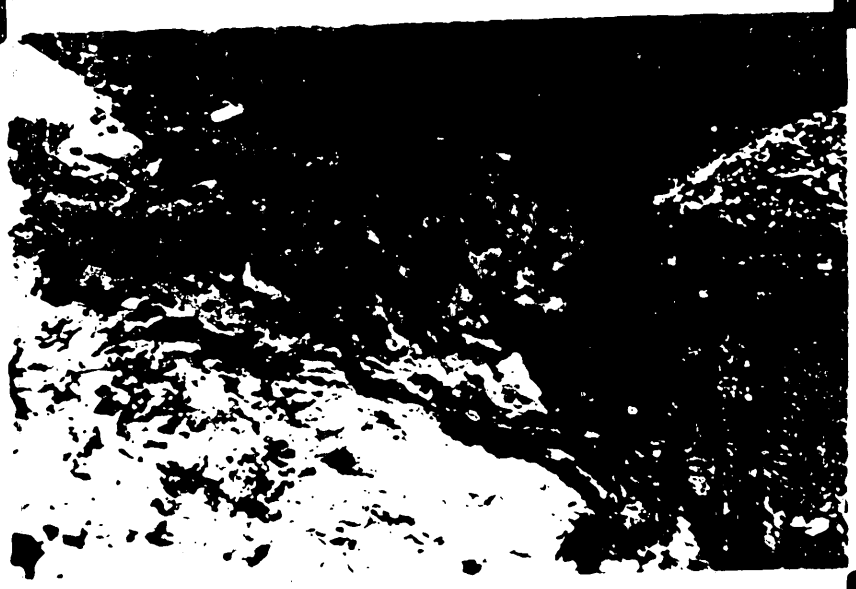

Figure 38.—Slumped Bryson formation and Devils River limestone in a "cave-fill zone" at the Mariposa mine, developed where a vertical fracture intersects the topmost limestone beds. The white rock in the lower left part of the photograph is Devils River limestone and the darker rock above is Bryson formation. The beds were horizontal before solution and slumping occurred.

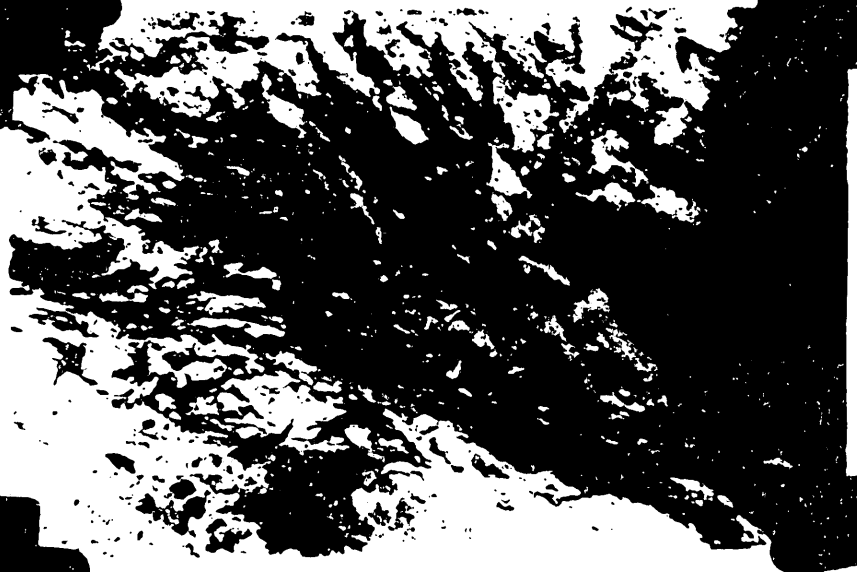

Figure 39.—Closer view of the "cave-fill zone" at the Mariposa mine. To the right of the photograph the beds swing upward to complete the syncline. In mine workings below, the beds are horizontal and relatively undisturbed.

Figure 40.—Mineralized "cave-fill zone" in the Greene mine. The bright red cinnabar (dark in the photograph) is deposited between the Devils River limestone at the lower left and the slumped Grayson formation at the upper right. At the lower right is the top of a mine tunnel. Width of area shown is [illegible] feet.

limestone would have its diameter determined by the arching strength of the Devils River limestone and, once started, would tend to stope on up through the Grayson, forming a breccia pipe. On the other hand, the formation of a collapse structure caused by undermining at the top of the Devils River limestone would be accompanied by almost immediate settling of the weak Grayson rocks. This settling would tend to slow the solution process at the place it initially began and cause lateral spreading along the controlling fracture, thus forming a cave-fill zone. As the Grayson is relatively impermeable, a corollary to this hypothesis is that the solvent waters that caused the cave-fill zones were ascending and migrating laterally, for it is not to be expected that descending waters would have their flow concentrated along the base of the Grayson. Ascending waters might be either hydrothermal or artesian meteoric waters.

Relation to limestone caverns

The Devils River limestone, the only thick limestone formation in the region, contains many solution caverns, most or all of which were probably formed during the same period as the breccia pipes and cave-fill zones.

In general there are two kinds of caverns, vertical caves developed mainly along fractures, and horizontal caves developed mainly along bedding planes. Vertical caves are found in the Little Thirty-Eight mine and in the Centennire workings of the Mariposa mine, for example. Vertical caves are usually less than 10 feet wide but locally swell to 50 feet or more in width. The length and height reach hundreds of feet.

Horizontal caves occur in the Waldron mine and in the Contraire workings of the Mariposa mine, among other places. Single rooms in the horizontal caves are rarely more than 100 feet in width and their height, though generally small, may reach 50 feet or more.

The antiquity of some of the caverns is established by their relation to mineralization and to the cave-fill zones. Coatings of siderite and coarsely crystalline hydrothermal calcite line the walls of many of them, as for example at the Waldron, Little-Thirty-Eight, Harlosa, and Alios mines. Other caverns are smooth-walled and bare, for ordinary dripstone is very rare. These caverns also may be ancient and the hydrothermal solutions were not depositing in them or did not have access to them. One such cavern is a large open sinkhole near the Waldron mine; it is probably an ancient cavern, de-roofed relatively recently. Cave-fill zones are commonly associated with open caverns occurring at greater depth along the same fracture, and thus the two are probably closely associated in age and origin. In summary, many of the caverns, like the breccia pipes and cave-fill zones, can be proved older than the gold-silver mineralizations and the others are at least older than the present weathering cycle, for dripstone is not forming in them, they are not related to the present surface or to the present drainage system and most of the known caverns are never wet.

From the space and time relations it is believed that the breccia pipes, cave-fill zones, and limestone caverns are contemporaneous features caused by solution of limestone. Solution cavities formed at the top of the Devils River limestone collapsed almost immediately, because of

their weak roof of Cambrian rocks, and formed cave-fill zones. Solution cavities in the limestone below were preserved if their width did not exceed the maximum width at which their roof arches could stand. Wider caverns collapsed and resulted in the formation of breccia pipes. This interpretation is supported by the pre-quicksilver age of all these features. It is supported also by their close association. Although downward transitions from typical breccia pipes to filled caverns are nowhere well exposed, such transitions may be inferred with confidence. In the case of pipes extending far downward into the Devils River limestone, it is possible that the solution caverns are best developed at a depth of approximately 800 feet below the top of the Devils River; at this horizon thin-bedded strata are exposed in Santa Helena canyon nine miles south of the Terlingua district.

Hydrothermal versus ground-water solution

The interesting problem of whether the caverns, and therefore the cave-fill zones and breccia pipes, originated from solution by ground water or by hydrothermal waters is without a proved conclusion. Arguments can be advanced to show that either or both may be responsible to explain these remarkable structures. Caves and sinkholes are so common in limestone regions that their ground-water origin is not often questioned. On the other hand, hydrothermally formed solution features are abundant even in areas of nonsalcareous rocks. The channelways and pools of thermal springs, the load of dissolved material carried by hot-spring water, the hydrothermally formed ore shoots, and the replacement veins and ore bodies

are abundant evidence of the power of hydrothermal solutions to dissolve rock. The addition of volcanic heat and carbon dioxide to ground water would make a very effective hydrothermal solvent for limestone. At Terlingua, time and place relations give suggestive evidence of hydrothermal origin.

During the time when the Chisos volcanics were being deposited and the very numerous intrusions were being emplaced, normal ground water must locally have been replaced by heated water, and the heat of intrusions combined with their expulsion of magmatic water would energize upward movement of this water. In other words, there must have been periods when hydrothermal activity predominated over activity by downward moving cold ground water. Conditions such as exist in parts of Yellowstone Park today may logically be pictured. Because many of the pipes and caverns are mineralized, they must be as old as some of the hydrothermal activity. Indeed, some of the pipes and caves show evidence of being earlier than igneous rocks whose intrusion preceded mineralization. That the pipes were not formed before the beginning of igneous activity is proved in several instances by the occurrence of inclusions of Chisos volcanics in the breccia. Thus our best knowledge of time relations is broadly in agreement with a hydrothermal origin.

An enormous volume of hydrothermally deposited calcite is present in veins. Although the deposition probably extended over a long time, much of it was contemporaneous with or later than the formation of pipes, caverns, and cave-fill zones. The most logical source of the calcite is in the limestones, from which it could have been dissolved by hydrothermal solutions and re-deposited in veins closer to the surface or by hot-spring waters on the surface.

The space relationship of caverns and pipes with igneous intrusions and mineralized rock also is suggestive of a hydrothermal origin for the pipes. Several pipes are intruded by igneous rock. Although these pipes may have served only as channelways to which the magma gained access by chance, it would seem more likely that magma would find its way into a hydrothermally formed opening than into a ground-water cavern, because the former has a deeper continuation and may connect with the source of both the hydrothermal solutions and the intrusion. Much the same thing can be said of the calcite and dimmer mineralization in the pipes.

The regional distribution of caverns and pipes in relation to the known area of hydrothermal activity should be significant. Study had shown that the entire Terlingua district is an area of hydrothermal activity, and pipes occur throughout the district wherever the Devils River limestone is not too deeply buried. Although similar features have not been reported from the surrounding area even where the Devils River limestone crops out, it cannot be said with confidence that the pipes are limited to the mineralized area, because the surrounding region has not been examined in the necessary detail.

Finding a significant space relation of the breccia pipes, caverns and cave-fill zones with present or past ground-water tables might indicate a normal ground-water origin. On the other hand, the lack of such a space relation would not prove a hydrothermal origin, for ground-water flow is not restricted to the zone near the water table. [34] Consequently, caverns dissolved by normal ground water are not necessarily

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[34] Hubbert, M. King, The theory of ground-water motion: Jour. Geology, vol. 48, p. 986, 1940.
[35] Davis, W. M., Origin of limestone caverns: Geol. Soc. America Bull., vol. 42, pp. 965-1035, 1930.

concentrated at or above the water table. This statement is in accord with the observed tangled complexity and large vertical extent of caverns formed by normal ground water. In the Terlingua district, the wide distribution of solution features both above and to great depth below the present water table is noteworthy. The Two-Forty-Eight pipe extends more than 800 feet below the surface and several hundred feet below the water table in a region that is now semiarid. The Chisos pipe extends deeper than 800 feet and more than 100 feet below the water table. The Agaja pipe must extend to the Devils River limestone at a depth of more than 1,100 feet, and as the displacement is probably 1,500 feet at the surface, a cavern extending more than 1,500 feet down into the limestone is indicated (unless the cavern has more lateral extent than the breccia pipe above it). This fact suggests that the bottom of the cavern below the Agaja pipe is more than 2,000 feet below the present water table. Caverns and typical cave-fill zones in the Chisos mine also are found below the present ground-water table. At the time of formation in the Terlingua, these solution features had a cover at least several hundred and possibly several thousand feet greater than now. It seems clear that some of the solution features must have formed far below probable ground-water tables and under a thick cover containing impermeable clays. At the same general time that the solution features mentioned were forming at low elevations, others on the higher part of the Terlingua uplift were forming at elevations thousands of feet greater, for the uplift occurred before the pipes were formed. It seems clear that the caverns are independent of elevation and also of ground-water tables.

The ability of hydrothermal solutions to form caverns was recognized by Davis, 35/ who says, "In regions that are invaded by volcanic magma it is believed that warm juvenile water and carbon dioxide may ascend toward the earth's surface. This rising addition to descending ground water of meteoric origin would probably give it a great increase in solvent power while the mixture is still deep underground." Walker 36/ states that some of the caves at Tintic are formed by ascending hot water.

Although hydrothermal water is suggested as a more probable agent than ground water in forming the solution features, no implication that this hydrothermal water was all juvenile or magmatic in origin is meant. On the contrary, alteration such as the oxidation of sedimentary pyrite in the caverns and cave-fill zones would be difficult to explain by magmatic waters without any intermixture of oxygenated meteoric waters. The oxidation accompanied or preceded quicksilver mineralization and is not relatively recent, as is shown in some places by oxidized rock crusted over and sealed by hydrothermal calcite containing cinnabar.

The hydrothermal conditions postulated are similar to those that exist in areas of active thermal springs. Most modern students of thermal springs believe that meteoric water is an important or dominant constituent of the spring waters. Quantitative studies at Steamboat Springs, Nevada, 37/ have recently disclosed much new information. At this place the evidence indicates a large proportion of meteoric water, heated and admixed in various amounts with water and dissolved substances from a volcanic

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35/ Davis, W. M., op. cit., (Geol. Soc. American Bull., vol. 42), p. 487.

36/ Walker, R. T., Deposition of ore in pre-existing limestone caves: Am. Inst. Min. Met. Engineers Tech. Pub. 154, 1928.

37/ Brannock, W. W., Fix, Philip F., Gianella, Vincent P., and White, Donald E., Preliminary geochemical results at Steamboat Springs, Nevada: Amer. Geophys. Union Trans., vol. 29, pp. 211-226, 1948.

source. The water in the central hot core of the spring system rises because of its high temperature, while cool meteoric water migrates downward and into the spring system. 38/ A similar hydrothermal system may have been responsible for the solution features and hydrothermal mineral deposits in the Terlingua district. This explanation is in accord with the widespread volcanic activity, the wide distribution of hydrothermal quicksilver deposits, and the movement of immense quantities of calcium carbonate indicated by the limestone solution features and the calcite veins.

Possible relation of igneous plugs to breccia pipes

The important geologic problem of how necklike or small pluglike igneous intrusions make room for themselves is not completely understood even though Daubree, as early as 1891, 39/ made elaborate experiments, which he felt solved the problem. The intrusion of igneous rock into several of the Terlingua breccia pipes suggests that some of the small intrusive plugs in the district and the pipes may have a common origin. In addition to this occurrence of igneous rock in the pipes, the similarities in size and shape between plugs and pipes, as well as their association in space, also suggest that they have a common origin. For example, numerous small plugs on Contrabando dome have about the same shape and dimensions as the breccia pipes in this area. If one accepts the hydrothermal origin of breccia pipes, a theoretical sequence of events for the emplacement of a plug may be constructed.

38/ White, Donald E., personal communication.

39/ Daubree, A., Role Geologique Possible des Gaz a haute Pression, Soc. Geol. France Bull., 2nd series, vol. 19, pp. 313-354, 1891.

Such a sequence of events would be as follows: First, magma at depth expels fluids, which, with possible addition of meteoric water, rise rapidly because of their low viscosity and corrode their channelways where physico-chemical conditions favor solution. Calcite is reprecipitated as calcite veins closer to the surface, where the pressure is less, or is carried out in thermal spring waters. Collapse in the newly formed caverns starts the formation of breccia pipes. Second, simultaneously or later, some of the magma, which is relatively viscous and slow-moving compared to the solutions that preceded it, rises into the channelways and fingers into the breccia. Space for both the breccia and the magma is provided by transfer of rock toward the surface in solution. Third, the magma works upward chiefly along the walls of the breccia and fills any accessible openings. If the magma were under sufficiently great pressure it might eventually reach a level where it could overcome the confining pressure, flush the breccia out at the surface, and form a volcanic neck. Fourth, calcite mineralization and cinnabar mineralization take place in the igneous rock and the breccia. The sequence of events described differs from the processes studied experimentally by Daubree (discussed below) in that the violent mechanical tearing and melting out of a channelway is largely replaced by hydrothermal dissolving of a channelway.

Field evidence for relatively quiet igneous intrusion guided by breccia pipes is present in the Terlingua district, but no evidence was found for the postulated transition to the more vigorous process of extrusion. This fact would suggest that either the transition was so

abrupt that no intermediate structures remain or the breccia pipes and igneous plugs were formed when igneous pressure was at a low ebb. Breccia pipes that are intruded by igneous rock may represent intermediate stages in the formation of igneous plugs, but not intermediate stages in the formation of volcanic necks. More violet intrusion, to form volcanic necks, would be expected to shove the breccia upward, but no breccia bodies of this displacement have been found in the Terlingua district.

Theories of origin of breccia pipes elsewhere

The mechanisms of origin of breccia pipes (including filled sinkholes and volcanic necks) postulated by various writers may be roughly divided into four groups: (1) gaseous explosions or localized upward punches of magma; (2) intrusion stoping, gas fluxing, or melting; (3) "mineralization stoping" or removal of rock by rising solutions and consequent collapse; and (4) solution by ground water in regions underlain by limestone and resulting collapse.

Daubree's 40/ early experiments and his introduction of the term diatreme have influenced subsequent thought on the explosive origin of breccia pipes. He used a device adapted from a testing cylinder for explosives. It consisted of a central chamber containing dynamite or guncotton and a subsidiary chamber at one end containing a cylinder of the rock to be tested, through which the explosion gases had to pass in order to escape. The chamber containing the rock cylinder had in one end a hole of a diameter less than that of the cylinder for the

40/ Daubree, A., op. cit. (Soc. géol. France Bull., vol. 19).

explosive gas to enter, and in the other end a similarly restricted hole for the gas to exit after passing through the rock. The explosives used developed pressure of 1100 to 1700 atmospheres and temperatures of 2500° to 3200° C. The duration of the explosions ranged from 2/100,000 of a second for guncotton to 3/1000 of a second for dynamite. Each rock tested was cut into a cylindrical shape in such a way that a natural crack occupied a diametral plane of the cylinder or else a tiny hole was drilled along the axis of the cylinder. The purpose of using a crack or drilling a hole was to concentrate the explosive action and thus prevent a blowout around the outside of the rock cylinder.

The explosion holes produced in Daubree's tests had a roughly circular or elliptical cross-section. In a rock cylinder having a diametral crack the hole was zig-zagged like a lightning streak within the plane of the crack. In a cylinder with a drilled guide hole the explosion hole was fairly straight. Some of the material blown out of the holes was fused and some of it was clastic. It is worth emphasizing that in these experiments the holes were <u>gouged</u> out in distinction to being punched out. The gases began to leak out along a crack or hole and this was rapidly and violently enlarged by tearing and melting away of small pieces.

Daubree concluded that the effectiveness of high-pressure, high-temperature gases in producing openings was proved, and he felt that the experimental results were directly applicable to the formation of pipes of different kinds, such as the South African diamond pipes and volcanic necks. He pointed out the striking contrast between the usual linear ruptures of the earth's crust and diatremes.

W. H. Emmons 41/ has assembled comparative data on a large number of pipes, and he interprets most of them as diatremes or incipient diatremes, blown through the rock by gases. The structures included in his discussion range from vein systems believed to represent incipient diatremes to volcanic necks, which are also believed to originate by explosion. The material within at least one of these pipes is below its stratigraphic position; in most of them the direction of displacement is not known. Limestone occurs in some of the areas containing pipes.

The second group of theoretical mechanisms involves the progressive stoping off and possible melting of portions of country rock at the top of an intrusion. The idea of mechanical stoping from the roof by veining, unequal heating, and magmatic wedging, combined with the sinking of fragments, has been applied principally to intrusions of batholithic proportions. Smaller plugliko or neckline intrusions are supposed to have worked upward aided by the fluxing and blow-piping action of hot gases collecting at the top of the intrusion. 42/ A variation of the intrusion-stoping theories is intrusion followed by withdrawal, with collapse accompanying the magmatic withdrawal or relaxation. This process has been called upon to account for ring dikes. 43/

The third mechanism, mineralization stoping, was proposed by Locke 44/ to explain mineralized breccia pipes. He attributes their formation to

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41/ Emmons, W. H., Diatremes and certain ore-bearing pipes: Am. Inst. Min. Met. Engineers, Tech. Pub. 891, 1938.

42/ Daly, R. A., Igneous rocks and the depths of the earth: p. 360-361, 1933.

43/ Anderson, E. M., Tertiary and post-Tertiary geology of Mull, Loch Aline, and Oban: Geol. Survey Scotland Mem., p. 11, 1924.

44/ Locke, A., The formation of certain ore bodies by mineralization stoping: Econ. Geology, vol. 21, pp. 431-453, 1926.

removal of rock along trunk channels by rising solutions during an early stage of their activity, collapse and brecciation of the rock thus left unsupported, and deposition of ore and gangue minerals in the brecciated zone." In some of Locke's examples, the breccia has a measurable downward displacement. Furthermore, he cites two examples of breccia pipes in which "the actual downward terminations are visible; there is a rapid convergence of the walls forming a rude keel below which the silicified breccia descends only in irregular protuberances. No intrusive plug appears in either case and the hypothesis that such a plug has advanced and retreated is inadmissible." 45/ It is interesting to note that Emmons cites as examples of diatremes some of the same pipes that Locke regards as products of mineralization steping.

Solution by ground water and collapse is a fourth possible mode of origin for breccia pipes in regions underlain by rocks susceptible to solution or chemical attack. Thus subsidence over salt deposits, and oxidation subsidence above sulfide deposits, are obvious examples that can be observed actively taking place. In many instances, it is equally clear that solution of limestone by meteoric waters has occurred. Because the adequacy of meteoric waters to dissolve limestone is well known, nearly all solution features in limestone are ascribed to meteoric water, even in hydrothermally mineralized areas. It seems apparent, however, that hydrothermal waters are at least equally adequate solvents and must be considered as dissolving agents in any area where their former presence is indicated.

45/ Locke, A., op. cit. (Econ. Geology, vol. 21), pp. 446-447.

Missouri sinkholes and diatremes.—Grawe 46/ has described numerous pyrite-bearing breccia pipes in Missouri. He explained them as meteoric water solution features in which meteoric waters deposited pyrite. Although Grawe's report treats only the pyrite deposits, some of the structures contain galena, sphalerite, and barite, in addition to pyrite. Evidently because the breccia pipes, or sinkholes, are regarded as of meteoric origin, Grawe regards the sulfide minerals as products of ground-water solution of the traces of these minerals in surrounding rocks and re-deposition in the breccia pipes. Tarr 47/ believes the same deposits were formed by magmatic acid solutions in galleries and shafts dissolved by ground water. Although Tarr postulates acid magmatic solutions, which would certainly attack limestone, he regarded ground water as the agent that dissolved the limestone. The close similarity of some of the Missouri breccia pipes to Terlingua pipes, which are of probable hydrothermal origin and contain quicksilver mineralization of unquestionable hydrothermal origin, suggests that a hydrothermal origin for the Missouri structures should be considered.

In southeastern Missouri there are numerous breccia pipes similar in size and form to those described by Grawe and Tarr. However, some of these pipes contain igneous intrusions into the breccia, and therefore the breccia pipes in this region have been ascribed to explosive volcanism. In describing them, Rust says, 48/ "It is very common to find limestone fragments carrying Devonian fossils in a rock which also contains an abundance of granite inclusions. The granite pieces have come

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46/ Grawe, O. R., Pyrite deposits of Missouri: Missouri Geol. Survey, vol. 30, 1945.

47/ Tarr, W. A., Origin of the marcasite sinkhole deposits of central Missouri: Am. Mineralogist, vol. 22, pp. 830-841, 1937.

48/ Tarr, W. A., The barite deposits of Missouri: Econ. Geology, vol. 14, pp. 46-78, 1919.

48/ Rust, George W., Preliminary notes on explosive volcanism in southeastern Missouri: Jour. Geology, vol. 45, p. 61, 1937.

up several hundred feet and the Devonian fossils are at least 3,000 feet below their source beds. These two rock types, normally separated by about 4,000 feet of sediments, are found side by side at the intermediate Cambrian horizon of the area." Rust explained these conditions as due to explosions, following which magma rose into the debris-choked explosion tubes, incorporating the debris in the tubes. Would not collapse-stoping due to hydrothermal solution in the Cambrian limestone and possibly in the underlying nonmalcareous rocks better explain the predominant downward movement of the breccia fragments? Later intrusion would account for any upward movement of fragments.

In the same area, an ultrabasic intrusion with a pipelike form has been described by Singewald and Milton. 49/ The intrusion has a slightly elliptical outcrop with the longer axis 200 feet long, and drill holes indicate that it is about vertical. The surrounding Bonneterre dolomite is brecciated and metamorphosed at the contact, and the breccia contain calcite, galena, sphalerite, marcasite, chalcopyrite, pyrite and smoky quartz. In origin, it was believed by Singewald and Milton to be analogous to a diatreme.

From the published descriptions it appears that some of the sinkholes of central Missouri are very similar to some of the diatremes of southeastern Missouri with the exception that several of the latter also contain intrusions. At Terlingua, where the evidence strongly refutes explosive volcanism as the origin, several of the breccia pipes

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49/ Singewald, Joseph T., Jr., and Milton, Charles, An albite pipe, its contact phenomena and ore deposition near Avon, Missouri: Jour. Geology, vol. 38, p. 54, 1930.

also contain intrusions. This suggests that explosive action is not necessarily the origin of the southeastern Missouri structures. If the origin was not by explosion alone, then hydrothermal solution may well have played a part. It is hoped that future geologic work will reveal more definite criteria of origin.

General structural problems

Age relations

The structural evolution of the Terlingua district since the deposition of the Cretaceous rocks, involving folding and faulting, cannot be considered apart from igneous activity and mineralization. From the evidence in the district it has been possible to determine the relative ages of these events, though not their exact geologic ages or duration. The evidence bearing upon the extrusive and intrusive igneous history is fragmentary, because only isolated remnants of the lavas are left and because the intrusions, likewise, are generally isolated from one another.

The earliest major structural movement involving the Cretaceous rocks was probably the beginning of rise of the Terlingua uplift. The best evidence for this is found on the Terlingua uplift near the Fresno mine, where Chisos volcanics rest with angular unconformity on the lower member of the Boquillas flags. The intervening upper member of the Boquillas flags, Aguja formation, and Tornillo clay are not present and must have been either stripped away before deposition of the volcanic rocks or never deposited. Most, but possibly not all, of the uplift occurred before accumulation of the volcanic rocks. In contrast to

these conditions, Ross found conformable relations between the Chisos volcanics and the older rocks east of the district. Furthermore, near the Marathon area, King found anticlines in which the volcanics were involved, and he concluded that a considerable part of the uplift of the Marathon dome took place after the Tertiary volcanic eruptions. Thus it is clear that the Terlingua uplift cannot be exactly contemporaneous in origin with the Marathon uplift if the volcanic rocks in the two areas are exactly contemporaneous. However, there is no reason to believe that the Terlingua and Marathon uplifts originated simultaneously or even that all parts of the Terlingua uplift formed simultaneously, although the relation of both uplifts to the Sierra Madre makes it probable that they are part of the same orogeny. Similarly, the volcanic rocks may represent in the aggregate a long period of time, 50/ for little detailed information about these rocks is as yet available. Until more is known of the volcanic history of this whole region, the safest tentative conclusion is that the rise of the Terlingua uplift began before volcanism, continued well into the period of volcanism, and ceased before the close of volcanism.

The graben faults are clearly related in origin to the Terlingua uplift, because they die out on its flank, the Terlingua monocline. This relation of the monocline and the graben in space may be interpreted as indicating a close relation in time of origin, although it does not prove a time relation.

50/ The volcanic rocks have been dated elsewhere, by fossils in the tuff beds, as Eocene and Oligocene. See King, P. B., Geology of the Marathon Region, Texas: U. S. Geol. Survey Prof. Paper 187, p. 117, quoting Baker, C. L.; Bowman, W. F.; Berry, E. W.; and Plummer, F. B.

Widespread hypabyssal intrusion, accompanied by doming, overlaps the graben faults in age. The Cigar Mountain graben is younger than the Cuesta Blanca laccolithic dome, which it cuts, and yet it is older than the Cigar Mountain laccolithic intrusion, which has likelihood tensions along the southwestern fault of the graben. The faults of the Long Draw graben have served as channelways for intrusions, which are exposed in the Chisos mine, and yet later movement has displaced the same intrusions.

In summary, the age sequence of the major features begins with the rise of the Terlingua uplift. This rise was probably accompanied, especially in its later stages, by volcanism, by igneous intrusion and doming, and finally, by normal faulting.

The breccia pipes are younger than some of the volcanic rocks and older than some of the intrusions, as shown by their content of collapsed volcanic fragments and their invasion by intrusions.

Numerous minor faults and fractures of northeast trend, prominent because of mineralization by calcite and in some instances by cinnabar, overlap the breccia pipes and intrusions in age. The fractures originated in part before the breccia pipes, for the walls of the pipes locally follow preexisting northeast fractures. However, some of the fractures show postbreccia movement; many of them moved repeatedly. Northeast trending fractures occur in the igneous intrusions and also form channelways for the intrusions, as may be seen in the Mariposa mine, for example. The conclusion is warranted, therefore, that northeast fractures were formed before intrusions and breccia pipes, and that movement continued on northeast trends after intrusions and breccia pipes were formed.

Low-dipping sullions on parts of the Long Ba[illegible] aben faults may represent strike-slip adjustments accompanying sim[illegible] movement on the northeast fractures. The few small reverse faults in the district may belong to this period or may have accompanied the fol[illegible]ing of the Terlingua monocline at an earlier date.

It is noteworthy that the northeast fractures correspond in trend to the folds and thrust faults of the underlying Paleozoic rocks. The repeated movements on the northeast fractures may reflect new adjustments along the old underlying structures. The latest movements on the northeast fractures were accompanied by quicksilver mineralization.

In summary, the simplest structural sequence consistent with all the known evidence is represented diagrammatically as follows:

Rise of Terlingua uplift	————————
Normal faulting, including graben faulting	— — ————————
Volcanism	— — — ——— — —
Hypabyssal intrusion, accompanied by doming	— — — ————————
Formation of the breccia dikes	— —
Minor faulting (ending in ore deposition)	— — — — — — ————

The duration of this structural history is not known, and it may have covered a large part of the Cenozoic era. The subsequent geologic history of the district is mainly one of erosion modifying the surface of a structurally quiescent area, which, however, may have been subjected to regional tilting and uplifting.

Origin of the Terlingua uplift

The irregular Terlingua uplift, with a structural relief of thousands of feet and an area of more than 150 square miles, presents a problem in origin. It is distinctly different from the Appalachian type of folds caused by horizontal compressive stress, although such stress probably contributed to its monoclinally buckled margin. The high, circular dome of the Solitario, as well as the entire Terlingua uplift, of which the Solitario is a part, exhibits the form of a bulge that might be raised by a mobile igneous mass. The structural features of the region that includes the Terlingua uplift form the northern end of the Sierra Madre Oriental, 51/ and the uplift is elongated parallel to the narrow folds of the Sierra Madre, which lie far to the east and west of the Terlingua district; therefore, the Terlingua area was probably also under horizontal stress during the formation of the uplift.

The best-understood domical uplifts caused by intrusion of magma are laccoliths. Any intrusion postulated as the cause of the Terlingua uplift and the Solitario would be partly in the lower paleozoic rocks or below, for no intrusion of requisite size is exposed in the uplift, where erosion has laid bare all of the rocks down to the crystalline thrust-faulted paleozoic rocks. The magma might have intruded [illegible] the thrust planes or unknown structures in the precambrian rocks to form a floored intrusion or laccolith. An intrusion having the form of a laccolith under the uplift as a whole and a lysolith under the Solitario would plausibly explain the structure. It seems almost equally [illegible],

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51/ King, P. B., op. cit. (U. S. Geol. Survey Prof. Paper 215), p. 14[illegible].

on the basis of the structure alone, however, to postulate a stock or batholithic mass beneath the entire uplift. The areal extent of the uplift is as great as a small batholith, and it has been shown, by the work of Waters and Krauskopf for example, that batholithic intrusions may forcibly deform their wall rocks. 52/ Far above, with a cushion of intervening rocks, the results of batholithic intrusion might well be the formation of a structure such as the Terlingua uplift, and the erosion of the top of the uplift during its rise would reduce the load and stimulate further uplift.

On the other hand, the age relations and composition of the known igneous rocks must be considered in addition to the structural evidence. It has been shown that volcanism and hypabyssal intrusion were probably going on while the uplift was being formed; the volcanic and intrusive rocks are a varied suite from normal basalt to sodic rocks and normal rhyolite. These rocks could not logically have been derived from a more basic magma.

Large intrusions of basic rocks typically have the form, not of batholiths, but of laccoliths or lopoliths. 53/ An example of a basic intrusion, which is also soda-rich like many of the Terlingua rocks, is found in the Pilansberg complex. This complex of nepheline rocks, which is superimposed on the Bushveld complex in the western Transvaal, has been interpreted as a laccolith. 54/ It covers about 200 square miles and

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52/ Waters, A. C., and Krauskopf, Konrad, Protoclastic border of the Colville batholith: Geol. Soc. America Bull., vol. 52, pp. 1355-1418, 1941.

53/ Shand, S. J., Eruptive Rocks, second edition, p. 27, 1943.

54/ Shand, S. J., The geology of Pilansberg (Pilan's Berg) in the western Transvaal: Geol. Soc. South Africa Trans., vol. 31, p. 149, 1929.

has a probable thickness of 2,000 to 3,000 feet. It is thus of the same order of magnitude, though thinner, than the floored intrusion that would be required to produce the Terlingua uplift.

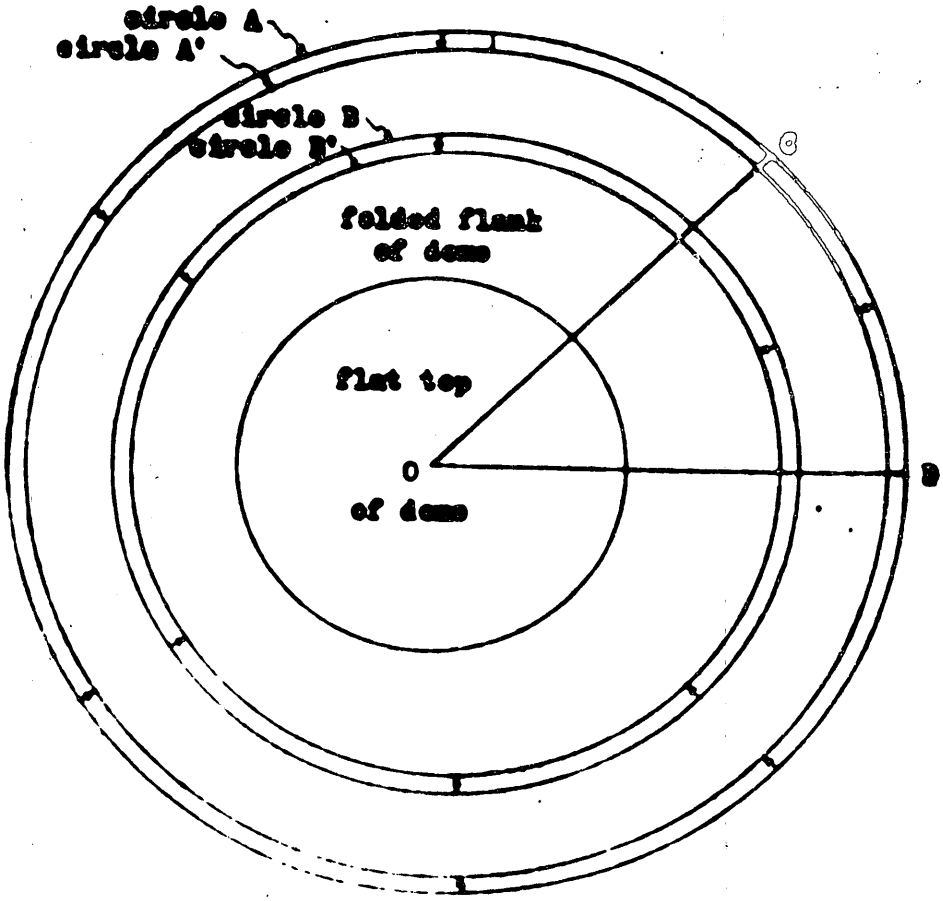
Origin of the domes

Although intrusive uplift is the indicated explanation for the Terlingua domes, horizontal stress is sometimes called upon to explain similar domes. Powers 55/ considered regional (horizontal) compressive stresses as a possible means of accounting for the Solitario dome. However, a consideration of the geometry of domes and the mechanics of "focusing" regional compressive stresses reveals that such an origin is difficult if not impossible.

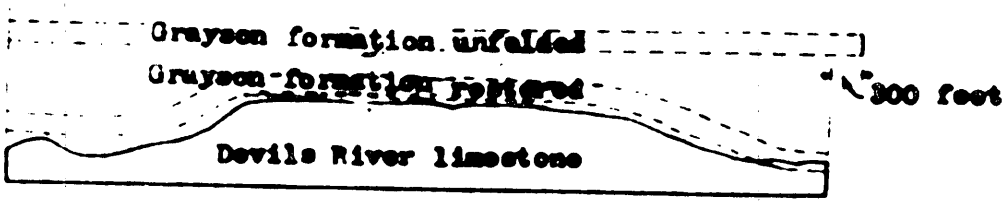
The problem may be demonstrated by trying to produce a dome in a sheet of paper without cutting or folding it radially. If one places his fingers around the edge of a disc of paper and pushes radially inward, linear folds result to form that dwarf any doming at the center. Additionally, rocks do not have the same physical properties as paper, but if they are strong enough to form a dome by radial compression, they would simultaneously form radiating anticlines or thrust faults. On the other hand, doming by a stress applied locally, as magmatic pressure, would have little or no regional influence because it would place the strata under horizontal tension instead of compression. Rocks are so weak in tension that tensional stress cannot be transmitted far.

The Black Mesa dome may be taken as a specific example. Figure 41 shows a cross-section of the Black Mesa dome with the Grayson formation

55/ Powers, Sidney, Solitario uplift, Presidio-Brewster Counties, Texas: Geol. Soc. America Bull., vol. 32, p. 419, 1921.



Diagrammatic map showing movement that would have been necessary to form Black Mesa dome by horizontal compressive stress. Arrows show direction and amount of movement. The dome was actually formed by vertical lifting; see text.



Vertical section across Black Mesa dome at F-F' on Plate 1. The eroded Grayson formation is restored to show the shape of the dome. Unfolding the beds increases the length of the section by 300 feet. Scale 1/25,000. One inch equals approximately 0.4 mi.

FIGURE 41

Diagrammatic map and vertical section of Black Mesa dome.

stated as a datum. As shown above the section, the Grayson unfolded has a length of 300 feet in excess of the length of the section; this of course is true not only of the Grayson but of the whole stratigraphic section. The distance of 300 feet represents the minimum shortening of any diameter of the dome that must have taken place if the dome were formed by horizontal compression. Assuming that this did happen, a circle just outside the dome would have its diameter and circumference reduced during doming by being pushed toward the center of the dome. The diameter would be reduced by at least 300 feet and therefore the circumference reduced by 300 times pi, or about 940 feet. How was the circumferential shortening of 940 feet taken up? This shortening is sufficient to create three radiating anticlines as high as the dome and with comparable dips. In the diagrammatic map of the dome, figure 41, circle B would be moved to the position of circle B', and likewise any larger circle such as circle A would be moved to A' and have its diameter and circumference reduced by 300 feet and 940 feet respectively. To form a dome by horizontal compression is therefore like pushing the sectors of a pie toward its center. If sector OOD in the diagram represents one sector of such a pie, it is readily seen that the part of the sector outside the presumed doming center of the pie would be thrust against neighboring sectors in such a way as to form folds or thrust faults radiating from the dome. There is good evidence against any such radial thrusts or folds at Black Mesa, for the surrounding rocks are well exposed. Nor does it help the question to suggest that the radial thrusting might be distributed on a number of joints, for the same might as well or better be said of the doming itself, which is no greater in magnitude than the required radial folds or thrust faults.

If the doming was caused by vertical lifting over an intrusion, there are still some interesting questions to be considered. One question concerns the apparent shortening of 300 feet across the dome. The effect of an intrusion would be local, and because rocks are weak in tensional strength, the tendency of the surrounding rocks to be drawn toward the dome would be slight. The shortening is therefore only apparent, and it is interpreted as actually a lengthening and slight thinning or even breaking of the strata on the flanks of the dome. That is, the Grayson formation, for example, was extended as it was bowed up and this extension of 300 feet across the diameter of the dome was probably accomplished by both plastic deformation and fracturing. The extension would be accomplished, not on the top of the dome, which is nearly flat, but on the flanks, where the rocks are strongly flexed. In spite of the magnitude of this extension, approximately an inch per foot, it was not noticeably expressed as unusual fracturing, probably because of the tendency of small fractures in the limestone to be healed by solution and re-deposition of calcite.

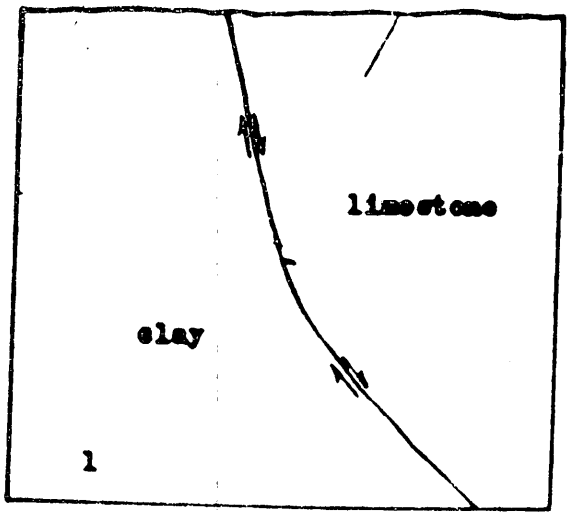
The intrusion that caused the doming may be at a depth of only a few hundred feet or it may be very deep, and it may be laccolithic or it may be plugliko or hypabithic. Small intrusions of trachyte are exposed in the Devils River limestone immediately north of Lemon Valley. No baked rock or other reliable evidence of the proximity of an intrusion at shallow depth could be found on the dome, but such evidence would not be manifest more than a few hundred feet at most above an intrusion, to judge from the contact effects of intrusions throughout the district.

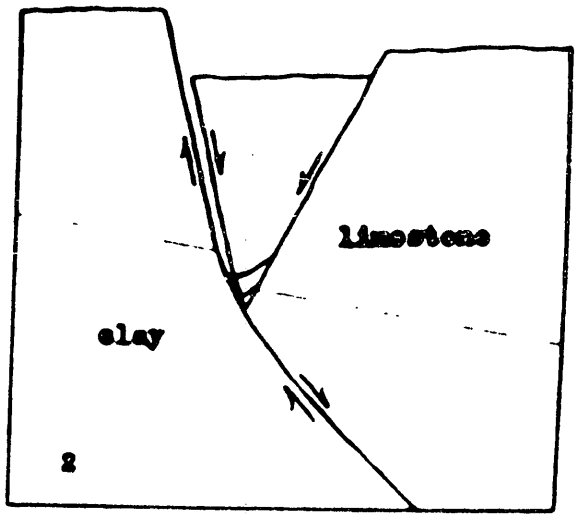
As to the type of intrusion, laccolith, bysmalith, or plug, there is no good evidence. It may be suggested, however, that plugs would form more readily in the softer rocks because these rocks yield plastically more easily and that large intrusions in the hard Devils River limestone would more likely be laccoliths or bysmaliths.

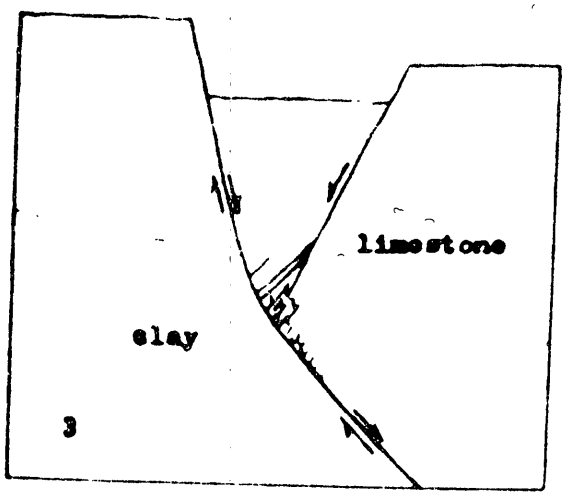
Origin of the grabens

Any theory of origin of the grabens must explain how space was provided into which the graben blocks could be depressed. This space (or potential space) may possibly originate by horizontal extension, or it may be inherent in a fluid or semifluid substratum of magma, but horizontal extension is independently indicated by the dip of the faults, which are not vertical. The explanation of some great grabens, or rifts, as a pair of thrust faults dipping away from each other and expressed on the surface by slides resembling normal faults has little to recommend it for the Terlingua grabens. The reasons for excluding this explanation are not detailed, for it is sufficient to note the general lack of structures caused by strong compression and the varied trends of the grabens.

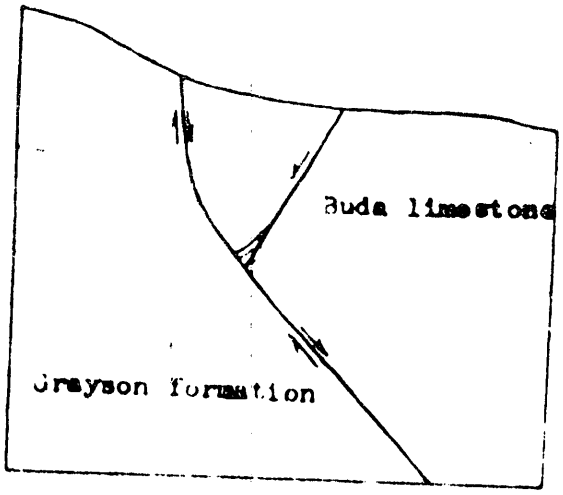
Fresno graben.—A small graben in the Fresno mine area, although not comparable in size with the principal grabens of the district, is significant because of the quantitative information on origin that can be obtained from a study of it. It was caused by the deflection in dip of a single master fault (fig. 42). This fault, which bounds the graben on the north, has a dip of about 80° in the Buda limestone and about 50° in the underlying Grayson formation. During the dip-slip







Vertical sections showing theoretical stages in the development of a small graben caused by the flattening in dip of a normal fault. Stages 2 and 3 occur simultaneously but are separated for clarity.



Vertical section of the Fresno graben. Scale: 1 inch equals 100 feet.

FIGURE 42

Vertical section of the Fresno graben and theoretical sections showing the development of a small graben

movement of 20 to 50 feet on this normal fault, the portion of the fault in the Bude limestone tended to open; this allowed a segment of the Bude limestone, bounded by a new fault on the south, to slide into the potential opening. Cross-sections of the graben and theoretical sections showing its origin are given in figure 42.

The marked difference in dip of the master fault in the Bude limestone and Grayson formation is adequately explained by the contrast in physical properties of these rocks. Knopf 56/ pointed out that the veins of the Mother Lode in California are deflected where they pass either in strike or dip from slate into greenstone. These veins occupy reverse faults, and their dip is greater in the slate than in the massive greenstone. Knopf cites as an example the contact vein of the Keystone mine, which dips at the surface 75° E., but after entering the massive greenstone, flattens greatly, dipping as low as 20° over large stretches. He calculated the index of refraction referred to slate as unity, and obtained a value of 1.4 to 1.6.

Moreover, the work of Griggs 57/ has shown that the angle between the applied compressive stress and rupture or shear failure varies with different materials and lessens with increase in brittleness. This fact is in accord with the findings of Knopf if the reverse faulting is assumed to have been caused by horizontal compressive stress.

For normal faults the direction of compressive stress may be taken as vertical, and the dips should be steeper in the more brittle rocks.

56/ Knopf, A., The Mother Lode system of California: U. S. Geol. Survey Prof. Paper 157, pp. 24-25, 1929.

57/ Griggs, D. T., Deformation of rocks under high confining pressures: Jour. of Geology, vol. 44, p. 555, 1936.

Newhouse 58/ illustrates the application of this generality to normal faults by a quotation from Dunham's work in the North Pennine region, England. According to Dunham, 59/ "The fissure veins of the Pennine type in all but a few cases occupy normal faults of small throw. The physical nature of the country-rock has had a profound influence upon the form of the deposits, for in hard beds the veins stand nearly vertical and are productive, while in the soft beds the veins dip at a low angle and carry practically no mineral material. Thus the wide parts of the veins are confined to sandstones and limestones while in shales only barren fissures occur."

The explanation of the small Fresno graben as due to the flattening in dip of a master fault, however, cannot be extended generally to the large grabens of the district. The southern part of the Long Draw graben has more aggregate displacement on the faults bounding one side than on those bounding the other side, but it is exceptional, and most of the grabens do not have such displacement. Nevertheless the origin of the Fresno graben throws light on the details of the large grabens, for changes in dip of the main faults have probably controlled subsidiary faults in many, if not all, of the grabens. Under increasingly deep burial, rocks progressively become less brittle and more ductile, and therefore it is expected that normal faults would generally flatten with great depth.

58/ Newhouse, W. H., Ore deposits as related to structural features, p. 14, 1942.

59/ Dunham, K. C., The genesis of the North Pennine ore deposits: Geol. Soc. London Quart. Jour., vol. 90, pp. 693-694, 1934.

The large grabens.—Two main lines of evidence on the origin of the large grabens are available: the geometry of the grabens and their space relation to the Terlingua uplift.

The geometry of the grabens indicates that they are relatively superficial accompaniments of horizontal extension; that is, they may be caused by plastic extension of deep rock (or magma), which is relatively ductile, and rupture of shallow rock, which is relatively brittle. The faults bounding the individual graben, if extended downward on the dips measured at the surface, converge rapidly and join at depths of only about a mile on the average. Such a geometric form might be produced also simply by folding or doming, in which the upper strata are extended most; but if this were the correct explanation, the grabens should be along the zones of greatest upward bending, and such is not the case.

The space relation of the grabens to the uplift suggests that they may have been formed because of the igneous intrusion beneath the uplift. An intrusion might control graben faulting in several ways: withdrawal of magma along tectonic lines may cause graben collapse; 60/ the presence of magma beneath an area subjected to deformation by a force couple should favor the formation of graben; 61/ or lateral igneous expansion below the surface might be accompanied by graben faulting in the surface rocks. The space relation of the grabens to the uplift is indicated chiefly by the marked tendency of the grabens to be coextensive with the

---

60/ A discussion of volcano-tectonic graben is contained in Howel Williams, Calderas and their origin (Univ. of Calif. Bull. Dept. Geol. Sciences, vol. 25, no. 6, pp. 309-311, 1941).

61/ Willis has shown that a graben block, once it has been outlined by faults, would tend to sink isostatically, horizontal extension permitting. (Willis, B., Normal fault structures and others: Amer. Assoc. Petroleum Geologists Bull., vol. 30, no. 11, 1946.)

uplift. A relation is further implied by the graben displacements, the vertical components of which are less than, or equal to, the vertical displacement of the uplift. Although horizontal movements cannot be measured with accuracy, available data suggest that the apparent horizontal shortening, due to uplifting, is of the same order of magnitude as the apparent horizontal extension, due to faulting. Along section AA', plate 1, the apparent shortening, due to uplifting and folding, is 1,100 feet; the apparent extension, due to faulting, is 1,600 feet.

Combining the foregoing evidence with what is known of regional deformation and of age relations, a somewhat hypothetical geologic history of the grabens is derived. Certainly the region was subjected to compression from the northeast and southwest. Widespread igneous intrusion, guided by earlier northwest trending structures, was probably contemporaneous with relaxation of the compression. The injection of magma into faults and folds must have been accompanied by some lateral extension in a northeast-southwest direction, partly reversing the compressional movement in this direction. Whether the lateral extension was the direct result of igneous expansion, or is attributable to the operation of a force couple, remains unanswered. A regional force couple applied during intrusion would help to explain the dominant northwest trend of the normal faults but, without igneous expansion, might not explain as well the non-typical normal faults of northeast trend (such as the Black Mesa graben zone). Simple withdrawal of magma, without assistance from other structural movements, fails to explain the horizontal extension.

It seems evident from this discussion of the origin of the Terlingua grabens that varied forces and movements must have been operative to form the grabens and that, therefore, regional stresses, igneous activity, and, locally, fault deflections, may all have cooperated. A sounder and more detailed theory of the origin of the grabens must await further knowledge about the structure of a larger area.

GENERALIZED GEOLOGIC MAP SHOWING STRUCTURE OF TERLINGUA UPLIFT AND SOLITARIO

Extent of Terlingua district shown by dashed line.

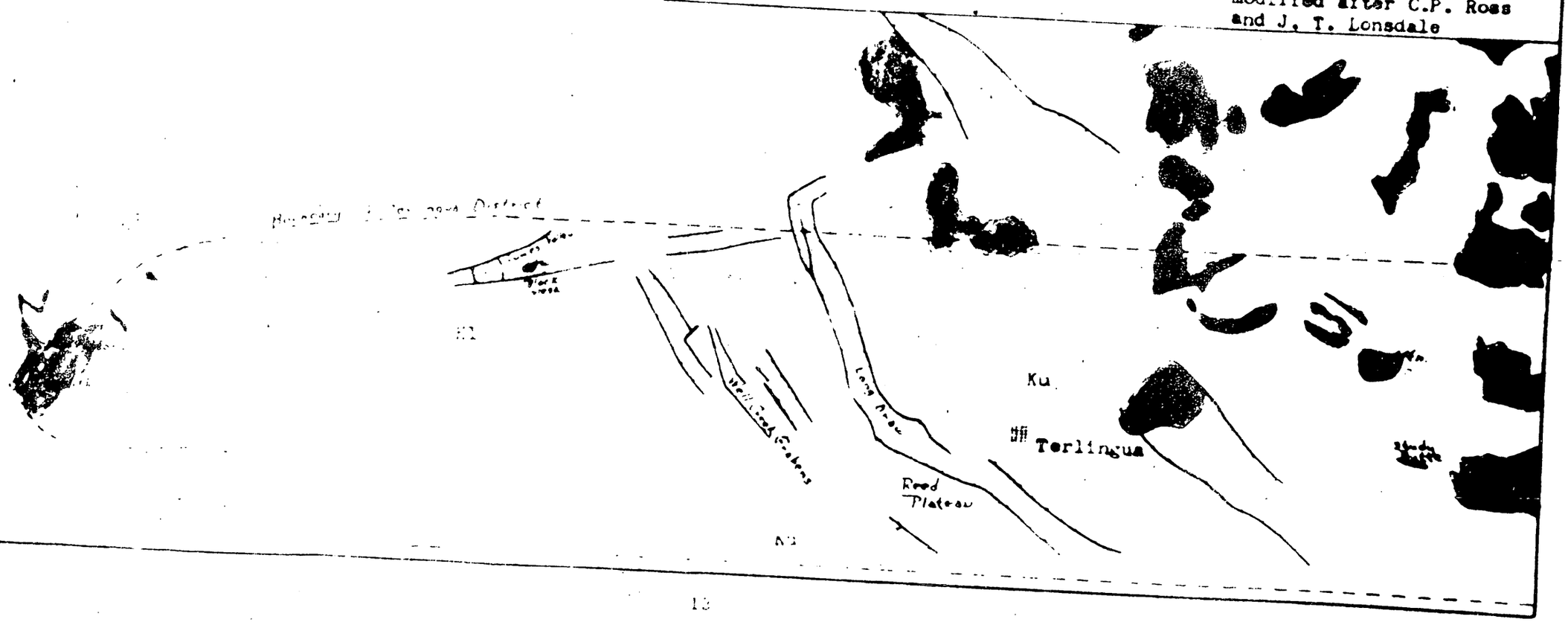
Scale

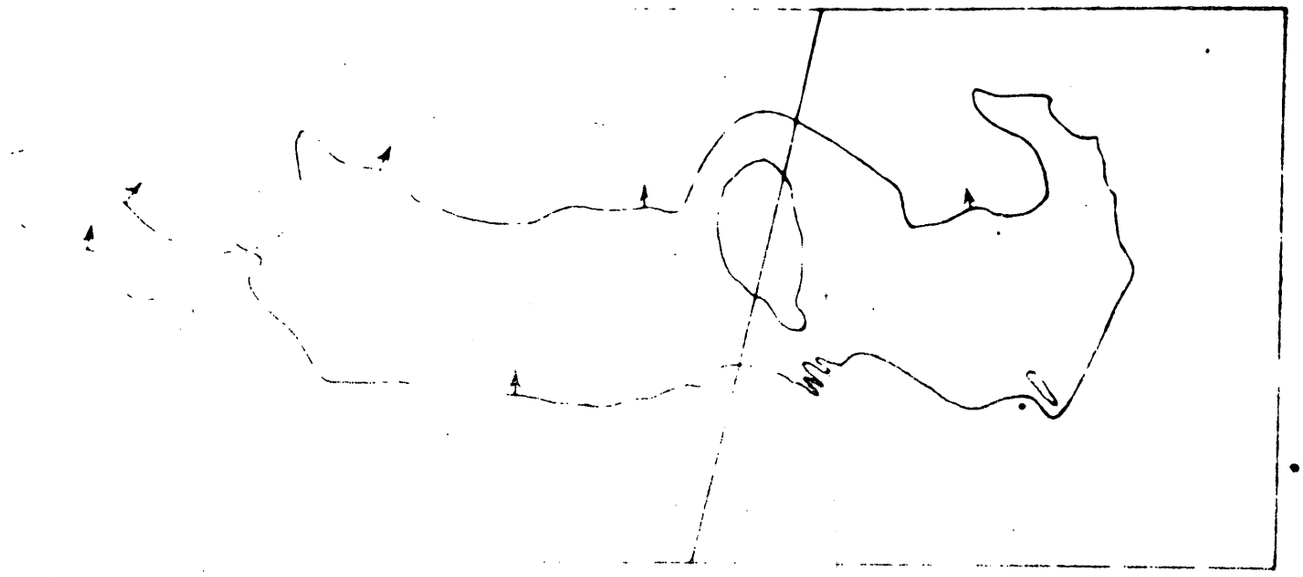
ROCKS

Tertiary and upper Cretaceous	Tv	Chisos volcanics.
Mesozoic	Ku	Upper Cretaceous rocks (Boquillas, Terlingua, Aguja, Gresser, Buda, and Tornillo formations).
	Kl	Lower Cretaceous rocks (Devils River, ~~Buda, and Del Rio formations~~; includes also older Cretaceous formations in the rim of the Solitario).
Paleozoic	Pal	Paleozoic rocks

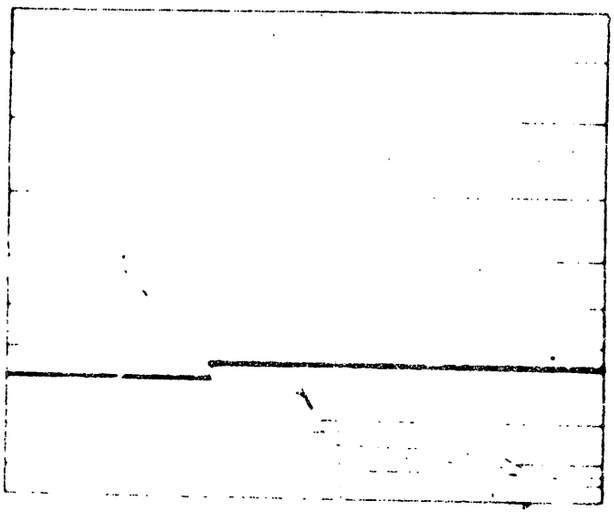
Intrusive igneous rocks

modified after C.P. Ross and J. T. Lonsdale

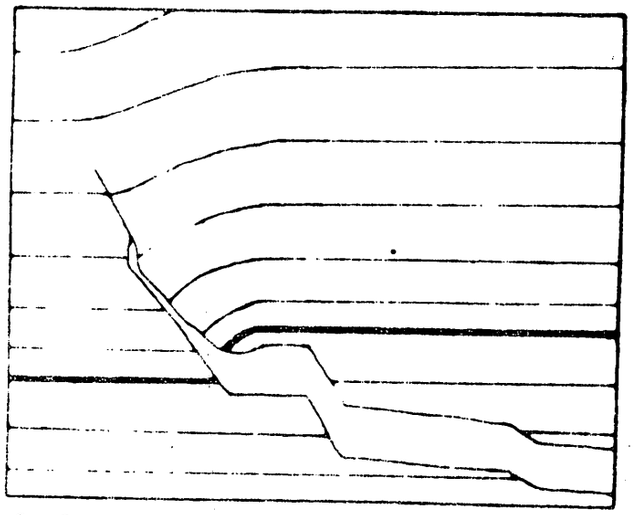




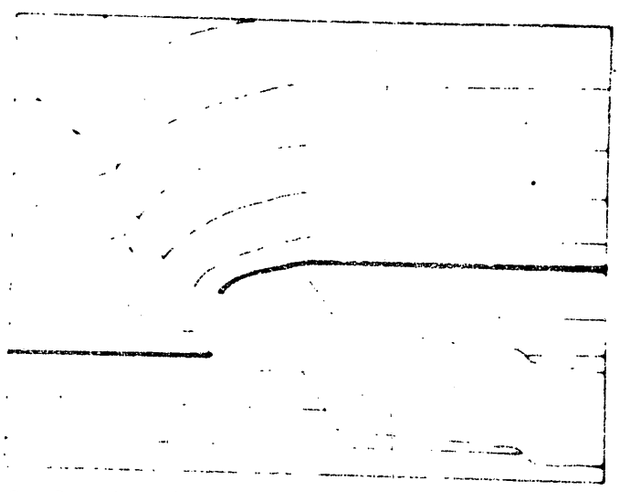
Outcrop of the intrusion. The intruded rocks are Terlingua clay. The line shown is the section line (1-4 below).



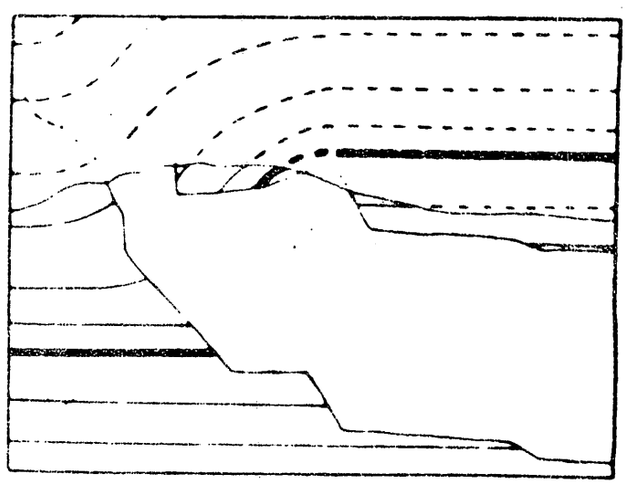
1. An early stage in the emplacement of the partly sill-like, partly dike-like intrusion.



2. Growth of the intrusion by thickening and spreading. The magma made way for itself by vertical lifting of the overlying rocks and thus created a monocline. Note that the vertical distance through the intrusion is uniform except beneath the fold, whereas the thickness varies.



3. Continued growth of the intrusion by vertical lifting accompanied by wedging open of the dikelike part at the left.



4. Present cross-section of the intrusion as determined from all available data, including surface, mine workings, and drill holes.

Figure 23

THE STUDY BUTTE QUARTZ SYENITE INTRUSION AND THEORETICAL CROSS-SECTIONS SHOWING PROGRESSIVE DEVELOPMENT OF THE INTRUSION AND ACCOMPANYING MONOCLINE. SCALE: ONE INCH EQUALS 400 FEET.

DMEA Form 7
(12-56)

OFFICIAL FILE COPY

Date	Surname	Code
9/27	Murphy	700
9/27	Ellis	700
"	Johnson	110
"	Mittendorff	100
		220

SEP 27 1957

Mr. Roger Butler, Vice-President
Trans-Pecos Minerals, Inc.
P. O. Box 191
Robstown, Texas

Re: Docket No. DMEA-4610 (Uranium)
Section 71, Block G-5
Presidio County, Texas

Dear Mr. Butler:

This is with reference to our letter of August 26, 1957, and previous correspondence with you by Mr. Clinton C. Knox, Executive Officer, DMEA Field Team, Region IV, Box 431, Joplin, Missouri.

As we have not received a reply to our letter, we are considering your application as having been withdrawn and are placing it in our inactive files.

We regret the necessity of taking such action, however, it is taken without prejudice to your proposed project. If at some future time you desire to reopen this case, you may do so by filing a new application, referring to the subject application by the DMEA docket number, and furnishing the information previously requested, together with any other information that you think might be helpful.

Sincerely yours,

C. O. Mittendorff (for)

Administrator

FMMurphy/izm 9-27-57
cc: Mr. Murphy
Admr.'s Reading File
THKiilsgaard, 5224
DMEA FT Reg. 4 (2)

8623

DMEA Form 7
(12-56)

OFFICIAL FILE COPY

Date	Surname	Code
8/26	Murphy	700
8/26	Ellis	700
"	Johnson	110
"	Mittendorf	100
8/26	Q.	220
		700

Mr. Roger Butler, Vice-President
Trans-Pecos Minerals, Inc.
P. O. Box 191
Robstown, Texas

AUG 26 1957

Re: Docket No. DMEA-4610 (Uranium)
Section 71, Block G-5
Presidio County, Texas

Dear Mr. Butler:

This is with reference to Mr. Knox's letter of June 14, 1957, relating to certain information which you promised to submit to his office.

As Mr. Knox has advised you, we prefer not to hold applications in abeyance for an indefinite period of time. Therefore, if the additional information required to process the above-referenced application has not been received by the DMEA Field Team, Region IV, or this office, within 30 days from the date of this letter, we will consider the subject application as having been withdrawn and will close the docket.

Sincerely yours,

C. O. Mittendorf (fw)

Administrator

FMMurphy/izm 8-26-57
cc to: Mr. Murphy
Admr.'s Reading File
DMEA FT Reg. IV (2)
THKiilsgaard, 5224

8623

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION
~~WASHINGTON 25, D. C.~~
Box 431
Joplin, Missouri
August 20, 1957

8/22 C 220
FMM 700

Mr. W. S. Martin, Acting Chairman
DMEA Operating Committee
Room 4459 - Interior Building
Department of the Interior
Washington 25, D. C.

Re: DMEA-4610(Uranium)
Trans-Pecos Minerals, Inc.
Section 71, Block G-5
Presidio County, Texas

Dear Mr. Martin:

With regard to the statement in your August 9 letter that you would appreciate my recommendation on this application, I recommend this docket be closed. This also is to assure you that no reply has been received to my June 14 letter sent to this Applicant as suggested in your June 6 letter. Therefore, since July 14, I considered this application as having been withdrawn.

I discussed it, however, with the Applicant's representatives, Messrs. Herman Wood, President, Roger Butler, Vice-President, and Carl Chelf, Consulting Mining Geologist, when at their Hazel copper mine project(Idm-E1084), near Van Horn, Texas, on July 16. They gave no indication that any of the necessary additional information for this DMEA-4610 application would be available. I got the impression from Mr. Chelf that no further work is warranted at this prospect under the present circumstances. I had formed such an opinion about 3 years ago from information through Mr. Harris Smith of Joplin, the landowner previous to Fowlkes Bros.; and Mr. Robert Pulliam of Alpine, Texas who did some of the early prospecting there and displayed some samples to me.

As I understand, the seemingly premature filing of this application by Trans-Pecos Minerals, Inc., was to comply with one of the terms of its lease from Fowlkes Bros. on whose ranch Mr. Wood is said to have been employed recently in some sort of supervisory

position. Maybe voluntary withdrawal of the application would jeopardize this Applicant's mineral rights. At any rate, its representatives did not follow my verbal suggestion for formally requesting withdrawal of the application.

I further recommend that at least two copies of the lengthy "Exhibit D" -- "Structural Geology of the Terlingua Quicksilver District" - photostated at considerable effort by this Applicant, but certainly having little or no bearing on its uranium prospect, may as well be returned upon the recommended formal closing of the docket.

Washington has one copy only. FMM

No. Applicant did not request return of supplementary material FMM.

Sincerely yours,

Clinton C. Knox

Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV

cc: DMEA Op.Com.
King,USGS,Denver
4610 file

DMEA Form 7
(12-56)

OFFICIAL FILE COPY

Date	Surname	Code
8-7	Murphy	700
8-7	Ellis	700
8/9	Martin	130
"	Johnson	110
"	Chatkendorf	100
8/12	P.K.	220
		700

AUG - 9 1957

Mr. Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV
P. O. Box 431
Joplin, Missouri

Re: Docket No. DMEA-4610 (Uranium)
Trans-Pecos Minerals, Inc.
Section 71 Block G-5
Presidio County, Texas

Dear Mr. Knox:

Reference is made to your letter, dated June 14, 1957, to the captioned Applicant advising that the application should be withdrawn if the information required could not be submitted within thirty days.

We would appreciate receiving your recommendation regarding the closing of this docket in the event you have received no reply from the Applicant.

Sincerely yours,

W. S. Martin
ACTING Chairman, Operating Committee (WB)

APPROVED:

P. F. Yopes (WB)
Member, Bureau of Mines

N. E. Nelson (WB)
Member, Geological Survey

FMMurphy/gla/izm 8-7-57
cc to: Mr. Murphy
Admr.'s Reading File
Operating Committee
THKiilsgaard, 5224

8623

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION
XXXXXXXXXXXXXXXXXXXX
WASHINGTON 25, D. C.
Box 431
Joplin, Missouri

ORIGINAL FILE COPY
DMEA
RECEIVED JUN 17 1957

DATE	INITIALS	CODE
6/17	C	220
"	~~FMM~~	~~700~~

June 14, 1957

Mr. Roger Butler, Vice-President
Trans-Pecos Minerals, Inc.
Box 191
Robstown, Texas

Re: DMEA-4610(uranium)
Section 71, Blk. G-5
Presidio County, Texas

Dear Mr. Butler:

With reference to your March 14 letter and the A.E.C. report, copies were made and sent to the Washington Office of DMEA to supplement the above-cited application. The reports you mentioned would be sent from time to time on the experiment you were preparing to conduct have not been received. Therefore, DMEA has requested me to advise you that it does not hold applications in abeyance for indefinite periods.

If, within 30 days from the date of this letter, you cannot submit all the information required in Washington for an appraisal of the merits of your application, I suggest that you should formally request its withdrawal. Then you could submit a new application when the required information is available.

Sincerely yours,

CCK/jd

Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV

cc: DMEA Op.Com.(2)
King,USGS,Denver
4610 file

DMEA Form 7
(12-56)

OFFICIAL FILE COPY

Date	Surname	Code
6/4	Murphy	700
"	Ellis	700
6/5	GCS	130
"	Northcutt	100
6/6	ZWJ	220
		700

JUN - 6 1957

Mr. Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV
Room 303, Post Office Building
P. O. Box 431
Joplin, Missouri

Re: Docket No. DMEA-4610 (Uranium)
Trans-Pecos Minerals, Inc.
Section 71, Block C-5
Presidio County, Texas

Dear Mr. Knox:

You forwarded a copy of the Applicant's letter, dated March 14, 1957, addressed to you, wherein it is stated that additional work was being done on the subject property and the results would be reported from time to time within a period of six months. However, we have received no copy of your response to that letter.

It is suggested that you write the Applicant advising that we prefer not to hold applications in abeyance for indefinite periods. If the Applicant cannot submit the information required to process the subject application within a reasonable time, it should withdraw the application and submit a new one when the required information is available.

Sincerely yours,

George C. Selfridge

Chairman, Operating Committee

APPROVED:

Frank D. Lamb

Member, Bureau of Mines

Thor H. Kiilsgaard

Member, Geological Survey

FMMurphy//gla
6-4-57
cc to: Admr.'s Reading File
Operating Committee
THKiilsgaard, Rm. 5224
FMMurphy, Code 700

8623

RECEIVED
MINERALS TECHNOLOGY
DIVISION

MAR 20 1957

BUREAU OF MINES
JOPLIN, MO.

March 14, 1957

United States Department of Interior
DMEA Field Team Region Four
P. O. Box 431
Joplin, Missouri

ATTENTION: Mr. Clinton C. Knox.

Re: DMEA 4610

Dear Mr. Knox:

Enclosed is a report from Mr. James W. Allison, Geologist, United States Atomic Energy Commission.

In view of his suggestions, and in view of the fact that Mr. Wood is now in the processing of assembling and moving equipment into the location in order to conduct the experiment suggested by Mr. Allison, please retain this case upon your docket and we will report from time to time within the next six months the progress made with this project.

Yours very truly,

TRANS-PECOS MINERALS, INC.

By
ROGER BUTLER

OFFICE FILE COPY
DMEA
RECEIVED
DATE CODE
3/25 C 220

RB:es
Enc.

UNITED STATES
ATOMIC ENERGY COMMISSION
ALBUQUERQUE BRANCH, DENVER AREA OFFICE
P.O. BOX 8009, STATION C
ALBUQUERQUE, NEW MEXICO

IN REPLY REFER TO: ABO:JWA

March 8, 1957

RECEIVED
MINERALS TECHNOLOGY
DIVISION
MAR 20 1957
BUREAU OF MINES
JOPLIN, MO.

Trans-Pecos Minerals
c/o Mr. Herman Wood
809 East Main
Robstown, Texas

Gentlemen:

I have completed the radiometric assay on the sample taken from Section 71, Block G-5, D&W RR Survey, and the results are as follows:

Sample No.	Type	Radiometric % eU3O8
F-41484	Select	0.19

This sample was selected from a zone 3 feet from the surface and had a 2-inch thickness showing yellow secondary uranium mineralization and the highest radioactivity of this property. The host rock is a white- to cream-colored tuff with a bentonitic seam having the mineralization.

The above-mentioned sample will be sent to Denver, Colorado for a chemical assay and the results forwarded to you. It is expected that it will be about two months before the results are received.

The drilling of several holes in the immediate area of this anomaly, as we discussed at the time of the examination of the property, should prove or disprove the value of this prospect.

If we can be of help to you in the future, please feel free to contact us.

Sincerely yours,

James W. Allison

James W. Allison, Geologist

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION
~~WASHINGTON 25, D.C.~~
Box 431
Joplin, Missouri

OFFICIAL FILE COPY
DMEA
RECEIVED MAR 13 1957
DATE | INITIALS | CODE
3/13 | C | 220
" | Murphy | 700

March 11, 1957

Mr. George C. Selfridge, Chairman
DMEA Operating Committee
Washington 25, D. C.

Re: Docket No. DMEA-4610(Uranium)
Trans-Pecos Minerals, Inc.
Section 71, Block G-5
Presidio County, Texas

Dear Mr. Selfridge:

This is in reply to your March 1 letter regarding the subject application.

During a telephone call from Mr. Roger Butler, representative for the Applicant, Corpus Christi, Texas, on March 7, he explained that plane table mapping of the Section 71 uranium prospect was in progress. However, he considered it advisable to delay supplying the additional information promised in his January 19 letter yet for possibly a month until some data expected from the AEC men, said to be working on that prospect, becomes available through their Albuquerque office. Mr. Butler was much more seriously concerned, however, with the undue delay in rendering a decision on this company's application on the Hazel copper mine, Cuberson County, Texas, DMEA-4476. I assured him that every effort was being made to submit the joint Field Team report and recommendations to you as soon as possible. I hope this can be done by March 20.

During his several previous telephone calls I had outlined the suggested alternative project proposal which will be recommended in our report on the basis of the draft of the geologic report and recommendations which I received from the Survey Member of the Field Team January 21.

Note
Kluqeschied handling 4476
read this letter. Murphy

Sincerely yours,

Clinton C. Knox

Clinton C. Knox
Executive Officer, DMEA
Field Team, Reg. IV

cc: DMEA Op. Com.
King, USGS, Denver
4610 File

DMEA Form 7
(12-56)

700

OFFICIAL FILE COPY

Date	Surname	Code
3/1	Murphy	700
3/1	Kupook	700
3/1	Selfridge	130
"	Johnson	110
"	Mattenson	100
3/4	C	220
		700

MAR - 1 1957

Mr. Clinton C. Knox
Executive Officer
DMEA Field Team, Region IV
Bureau of Mines
P. O. Box 431
Joplin, Missouri

Re: Docket No. DMEA-4610 (Uranium)
Trans-Pecos Minerals, Inc.
Section 71, Block G-5
PresidioCounty, Texas

Dear Mr. Knox:

Action on the above-referenced application is pending recept of the additional information promised by the Applicant in its letter of January 19, 1957.

We prefer not to hold applications in abeyance for indefinite periods; therefore, if the Applicant has not submitted the additional information to your office, we suggest that you inquire as to the approximate date it will be submitted.

Sincerely yours,

George C. Selfridge

Chairman, Operating Committee

APPROVED:

Frank D. Lamb

Member, Bureau of Mines

N. E. Nelson

Member, Geological Survey

FMMurphy/izm 2-28-57
cc to: Mr. Murphy
Admr.'s Reading File
Operating Committee
THKiilsgaard, 5224
JKratchman, AEC

8623

OFFICIAL FILE COPY DMEA RECEIVED JAN 31 1957		
DATE	INITIALS	CODE
1-31	C	220
1-31	Ellis	700
	Murphy	"

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
Washington 25, D. C.

Date January 30, 1957

DMEA Docket No. 4610
DMEA Contract No.
Commodity Uranium - Mercury
Name of applicant Trans-Pecos Minerals, Inc.
Name of property
Location of property Presidio Co., Texas
Estimated cost of project $74,280

To: Ernest William Ellis, DMEA Member
Uranium Commodity Committee
From: John E. Crawford, Bureau of Mines Member
Uranium Commodity Committee
Subject: Review of Application
(Application, Field Exam Report, Etc.)

1. Date of subject document: 1/19/57. 2. Date received by reviewer: 1/24/57.

3. Prior reports on this property known to reviewer: Yes ☐ No ☑

4. Prior reports on nearby properties known to reviewer: Yes ☐ No ☑

5. Information available on part production: Yes ☐ No ☑

6. Other pertinent factors known to reviewer: Yes ☐ No ☑

7. Further items noted yes above:

8. Refers to nothing special consideration:
- a. Location ☐
- b. Commodity ☐
- c. Evidence of mineralization ☐
- d. Geology ☐
- e. Proposed exploration method ☐
- f. Alternate exploration method ☐
- g. Costs ☐
- h. Hold in abeyance pending receipt of essential information. ☑

9. Action advised:
- a. Obtain information from applicant ☐
- b. Refer to Field Team ☐
- c. Denial ☐
- d. Agree with Field Team ☐
- e. Disagree with Field Team ☐
- f. Support alternate plan ☐
- g. Request another consideration ☐
- h. Approval ☐
- i. Consult with Mr. _____ at _____ AEC office.

10. Remarks: (Use back of page if necessary)

UNITED STATES
DEPARTMENT OF THE INTERIOR
DEFENSE MINERALS EXPLORATION ADMINISTRATION
WASHINGTON 25, D. C.

January 24, 1957

Trans-Pecos Minerals, Inc.
P. O. Box 191
Robstown, Texas

Subject: DMEA-4610

Gentlemen

Your application for exploration assistance, dated January 19, 1957 submitted to our office at Joplin, has been assigned Docket Number DMEA-4610 and referred to the Rare and Miscellaneous Metals Division in the Washington office. Kindly identify all future correspondence relating to your application by this Docket Number.

Sincerely yours,

(Sgd) Allen S. Dakan

Allen S. Dakan, Director
Operations Control and
Statistics Division

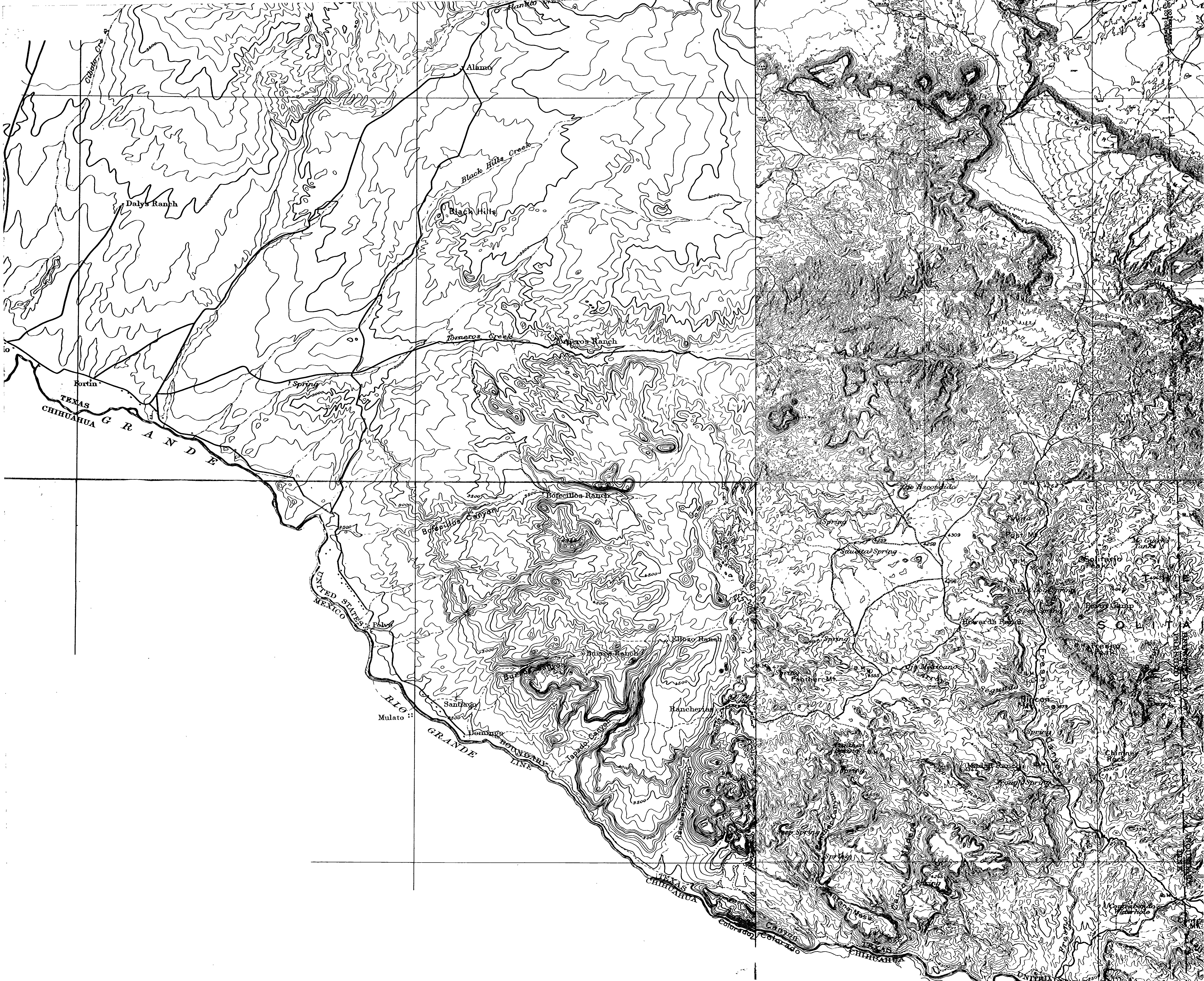
Copy to:

Region IV, Joplin, Missouri

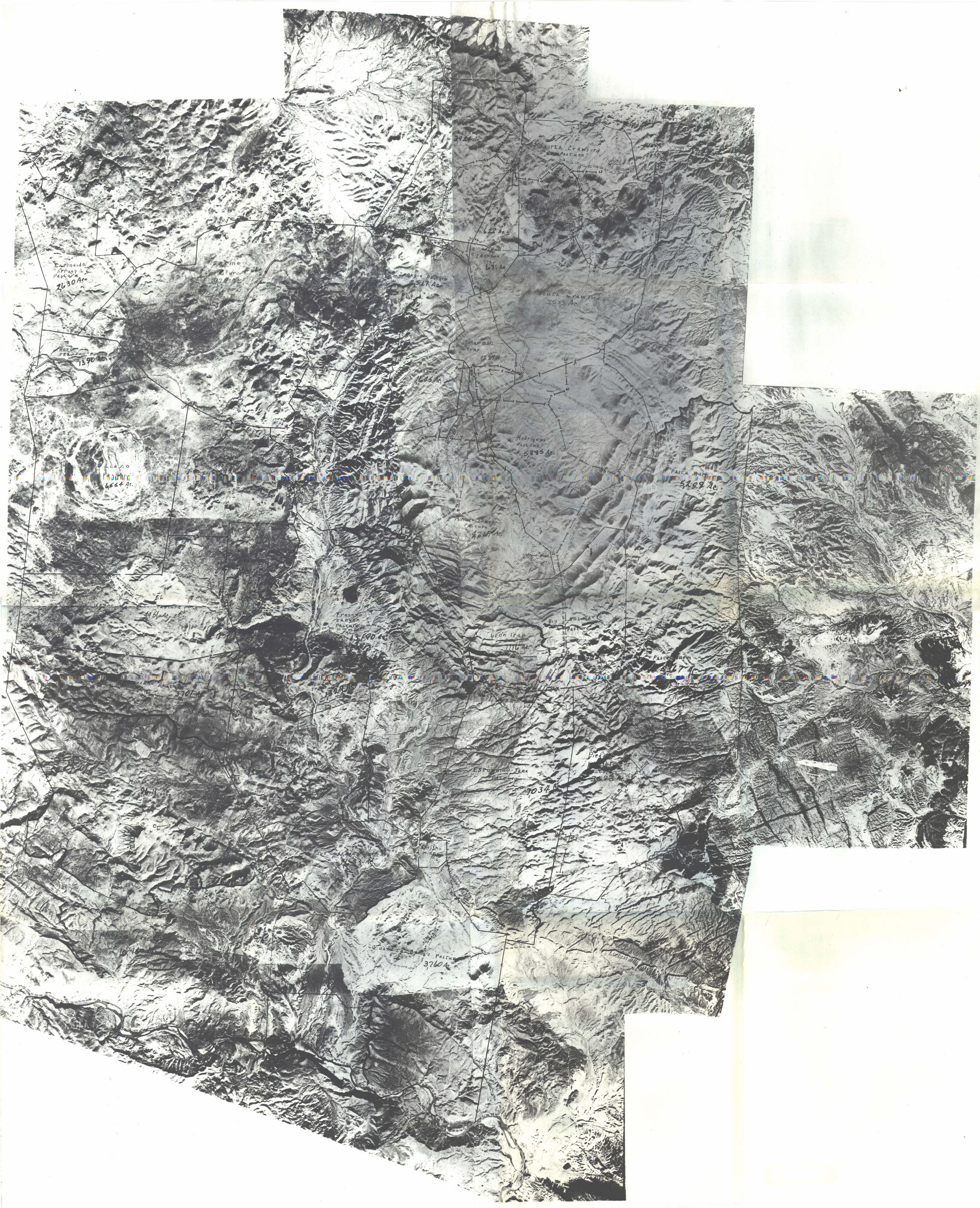
Code 700

See U.S.G.S. Prof. Paper 187-1937

6416


Cibolo Cre.
Alamo
Black Hills Creek
Black Hills
Daly's Ranch
Torneros Creek
Torneros Ranch
Fortin
Spring
TEXAS
CHIHUAHUA
GRANDE
Bofecillos Ranch
Bofecillos Canyon
UNITED STATES
MEXICO
Polvo
Elllozo Ranch
Burros Ranch
Santiago
Mulato
RIO
Domingo
GRANDE
BOUNDARY
LINE
Tapado Canyon
Rancherias
TEXAS
CHIHUAHUA
Colorado
Colorado
Canyon
Saucita Spring
Spring
Howard's Ranch
Panther Mt.
McGuirk's
Tanks
Solitario
Peak
SOLITA
Chimney
Rock
Fresno
Segundo
Madrid Ranch
Spring
Rincon
Mt.
Tapado Spring
Rough Spring
Seep Spring
Spring
Contrabando
Waterhole
UNITED STATES
MEXICO
RIO
TEXAS
CHIHUAHUA
Fresno

GEOLOGIC MAP AND SECTIONS OF THE TERLINGUA QUICKSILVER DISTRICT, TEXAS


North Crawford Pasture
Jackson Trap
631 Ac.
South Crawford
3533 Ac.
Jackson pasture
2517 Ac.
Enzino Pasture
Escondido Spring Pasture
2630 Ac.
Horse Trap
1390 Ac.
Sheaving Trap
Buen Pasture
1645 Ac.
Rodriguez Pasture
5895 Ac.
Pasta Buena
5288 Ac.
Llano Pasture
6654 Ac.
Fresno canyon Pasture
13490 Ac.
Big Solitario Pasture
León Trap
Pasta Bueno
Estrondido Tank Pasture
7034 Ac.
Quatro Bandos Pasture
3760 Ac.