Douglass College, Rutgers University, April 16, 1980

How chromosomes have been used to trace the origin and migration of races of maize in the Americas.

I. INTRODUCTION.

1. Reason for topic selection: Mysterious origin of the maize plant. The range of its diversity, both morphologically and in its chromosomes. The latter in conjunction with the former traces the origin of the races with considerable precision.
2. Conclusion from study: considerable antropological significance: Confirms, clarifies, tells much about relationships of areas of the Americas and of the type of agriculture within areas.
3. Maize, cannot propagate itself. Must be man planted. Seeds must be selected but what seeds are selected? The viability of the seed: need for constant renewal.
4. The importance of the maize plant in the U.S. What is grown? where did the different types of maize come from?
5. Most persons so far removed from agriculture that the importance of maize in the US may not be appreciated. It uses:

   Food: Cattle, hogs, poultry; absolutely basic to our economy.

   " : Corn-on-cob; canned corn; cornflackes; corn meal; hominy grits; corn starch; corn oil (Mayzola); corn syrup (glucose to fructose by enzyme treatment); pop-corn; corn-liquor!

   Commercial products: paper products, construction materials, ceramics; paints, explosives, enzymes, pharmaceutical products, corn-cob pipes!

   Supermarket: over 1000 items with some corn product in them.

6. Corn grown for different products not the same: yellow and white corn starch; sweet corn. Cattle corn. All from selected strains of maize. Where did these strains come from? How did we get to use them as they are used now? This takes us to the varieties of maize, its strange origin and diversity.

II. THE ORIGIN OF MAIZE GROWN IN THE ~~XXXXXXX~~ UNITED STATES AT PRESENT TIME, OR UNTIL very recently.

1. Goes back to the development of hybrid corn and its phenomenal take-over within a very few years. In 1933, estimated that less than ½ of 1 % of maize from hybrid techniques. By 1945, 90% hybrid corn.
2. Before 1933: what maize grown in the U.S. From maize that was in area: Indian tribes to early farmers and their selection methods. Open pollinated varieties: Named from farmer who selected it, from area where grown, some fancy name: Country Gentleman, Golden Bantam sweet corns here. Now, special hybrid varieties have equally fancy names: Indian Chief, etc.
3. Early maize in U.S. Areas: Indian maize, Arizona, New Mexico, Texas Oklahoma, north from Oklahoma;
   (2): Northern Flints: North east to Northcentral. Early maize.
   (3): Southern dents: Virginia and south.
4. Hybrid maize in U.S. developed mainly from two major sources:

   Northern Flints by Souther Dents, and selected strains among them. Other strains not grown; much of it lost. Loss ment loss of potential germplasm.for improvement of maize. This type of loss going on all over world for all types of crops. Very serious situation(in short run).

5. Preservation of some pre-hybrid maize from Indian tribes and from other parts of the U.S. William L. Brown, President, Pioneer Hi-Bred International, formerly Pioneer Hi-Bred Corn Company, started by Henry Wallace.

6. Method of corn breeding by hybrid methods: Shull, Cold Spring Harbor. 1908: The composition of field of corn. Maize very heterozygous. Self pollinated, over several generation, would segregate a variety of types of plants and ears. Heterosis: HYbrid vigor. Crossing inbreds to each other. Some showed remarkable vigor.

7. Shull, 1909: Pure line method of improving maize plant.

   Slow appreciation. During 1920s some experimentation at Ag experiment stations and with encouragement of maize head man in U.S.Department of agriculture. Henry Wallace, early recognition. Other followed. In less than 10 years, massive take-over of hybrid corn. Development of seed companies that made their own hybrids.

8. The general background for nearly all corn grown: economic reason initially: Texas cytoplasm. Male sterile. The 1970 disaster: spread of fungus desease.
   The potentials for such a disaster: the importance of maize in our very existence here in the US. Now obvious; no longer many small farms, dis ributed over country, using their own selected materials.

9. The situation recognized by some botanisits by ~~the~~ mid-ninteen fifties. Their fears resulted in action. This action responsible for my participation the ~~the~~ maize race story.

III. THE START OF THE STORY OF MAIZE RACES

1. Diversity of maize in the Americas long recognized.

2. Several botanists collected maize from parts of americas and attempted to classify the types. Very restricted study.

3. Maize grown in many parts of the Americas over the centuries. Result of man selections over these centuries, there arose many different types of maize. Each Indian tribe developed its own types and strains, and preserved them, or modified them.

4. Their selections: Flour corn, popcorn, sweet corn for making beer (chicha), ceremonial corn. Extreme importance in parts of the Americas. This shown by areas where maize grown before Columbus. SLIDE 1 (Weatherwax, map of maize distributions).
   Note areas of dense maize growing. The areas of little or none: many of these, maize came in only late, 500 A/D or later.

   The early areas of maize development: in regions of heavy speckling.

5. Selections for pigments in plant and ear: Andean maize, most prevalent. Examples of pigment in color: SLIDEs 2, 3.

6. Examples of types of ears: the different races:=distinct strains. SLIDE 4.

IV. THE BEGINNI GS OF AN EXTENSIVE STUDY OF MAIZE IN THE AMERICAS.

1. Began in 1940s. The Rockefeller Foundation-Mexican government contract to improve agriculture in Mexico. Instigated, 1943.
2. The areas covered, various crop plants. Wheat (green revolution), maize, potatoes, etc. Borlag, Wellhousen, wheat and maize. Young men, entusiastic, energetic.
3. The maize roject: If improvement is to occur, must know what maize types are available. The decision to collect maize all over Mexico.

   The mode of collection: 10 to 15 ears from each farmer to determine what maize he may be growing.

   Number of collection trips made to cover the whole country.
4. All maize grown was from v rieties known in the region where grown. No hybrid corn as was developing in the U.S. Much greater diversity of types.
5. The analysis: maize ears brought to Chapingo (Ag School, Rockefeller Foundation sectio) and placed on tables. Matching of types then occurred, What appeared to be hybrids of types clearly distinct from one another ordered. Then, plants grown from this classification to register comparisons and to reclassify, if necessary.
6. An example of this classification method and the consequences of it:

   Palomero Toluqueño, Cacahuacintle, Cónico, the cross of two suspected parents. <u>SLIDE 5.</u> (Names, Palomero, local in Valley of Toluca; Cacahuacintle= Caca, cocoa; cintle = maize. Maize with cocoa-like kernels. Common mode of naming maize races by Indians.

   Parent restriction in growth. The nature of kernels. The obvious distinctions: Morphology, starch --pop, hard flint; soft starch.

   The importance of the hybrid: a new <u>race</u>, like the open-pollinated varieties in the U.S. before hybrid corn took over. Kept that way by repeated selections for type. The effect of this hybrid race in Mexico: as itself, and as it contributed to other races; the <u>limited</u> distribution of its importance to races, and the significance of this for tracing the origin of the races. <u>SLIDE 6</u> Wellhausen Fig. 32, Cónico distribution.(<u>Chromosomes</u> and <u>origins</u>.)Verifications.
7. The publication, Harvard Univ. Press in English, 1952. In Spanish, 1951.

   Wellhausen and colleagues. Extraordinary document. Recognized 25 distinct races, and many hybrids between them. The distinct races divided into 5 categories according to methods used and mainly, an exceptionally active intuitive perception:

   (1). Ancient indigenous. 4 races
   (2). Precolumbian exotics. 4 races
   (3). Prehistoric mixtures. 13 races
   (4). Modern incipient races (new combinations from itroductions of foreign maize, hybridizing with indigenous maize). 4 races
   (5). Poorly defined races. 7. Our contribution to unraveling this class.
8. Subsequent collections and analyses of races over the Americas followed this pattern of procedure and its publication mode. The beginning of my entrance into this project.

V. THE FORMATION OF THE COMMITTEE FOR PRESERVATION OF INDIGENOUS STRAINS OF MAIZE. NRC:NAS. 1954-1955.

1. The impression made on botanists and agriculturists of the Races of maize in Mexico study: brought attention to the diversity of maize types, the effects of widely diverse germplasms from maize introduced crossed with maize indigenous to territory.

2. Hybrid-maize; recognition of its limited germplasm selection and loss of potential germplasms through neglect to continue open pollinated varieties in indigenous regions.

3. Fear that this same situation would occur over the Americas with loss of much of its extraordinary germplasm potentions, whereby selections had been made over hundreds of centuries of selection for mutations of the regulatory type and the nucleotide types.

4. Committee functioning in cooperation with the Rockefeller Foundation. Selections made all over the Americas as they wer made in Mexico. Studies of races in territories followed collections in same manner. Publications for each region examined:
   Mexico, Guatemala and Central America; Colombia, Venezuela, The Caribbean Islands, Ecuador, Peru, Bolivia, Chile, and one incorporating Brazil, and adjacent Agrentina, Paraguay, and the Guianas.

5. One man on committee had theory about the chromosomes; their distinctive constitution differences according to elevations where races grown. This required knowledge of chromosomes at one stage in development of plant: the prophase of meiosis in "pollen mother cells" where chromosome from ear parent synapsis side-b-side with chromosome, homologous, from pollen parent.
   June, 1957. Visit to C.S.H. for another purpose. Asked if I would be willing to train a person for such a study in Peru. My answer:Yes.

   Winter, 1957-1958. Training program in Ag. School, outskirts of Lima.

6. Following year, request to do same in Colombia, South America. My answer was Yes. Difficulties arose regarding person to trains. I decided, best for me to go directly to Colombia and eamine some of the material already collected, stored in bottles in the deep-freeze Decision to work there for 6 weeks and then return to the U.S. Period, from December 1978 through January 1959. Worked at Medellín, where maize grown for this study and adjacent to the Agr. School, supported by the Rockefeller Foundation.

VI. THE COLOMBIA EXPERIENCE.

1. Given bottles with pollen mother cells in them, collected from individual plants of races in Ecuador, Bolivia, and Chile, that were considered to be certainly indigenous to the area, not recent(very) introductions. Bottles and data available gave: name of country, name of race, collection number to identify just where collected, and elevation where collects. Missing, information on exact location where each race collection was made. This information was at the Station in Bogotá. It proved to be important.

2. What my job was: to examine the chromosome at the pachytene stage for any differences that might appear in them, particularly the <u>knobs</u>, enlarged deepstaining components. Necessary to explain them as these proved to be the key to this study of origin and migration of races in the Americas, along with two other or three other maize chromosomal types.

3. The chromosomes: Illustrations.

   SLIDE 7. Morgan photo.
   SLIDE 8. McC. photo medium to large knobs.
   SLIDE 9. Kato photos; heterozygous knobs.
   SLIDE 10. Diagram of knob positions, potentials. Abn. 10 and B-type.

4. Mode of examining material: completely random, without plan as I was not really interested in the job. It was a face-saving job only.

   Pick a bottle, record the chromosome constitutions for each plant:

   For each chromosome: presence or absence of a knob at knob-forming position, and for each homologue.
   If present, size and shape of knob recorded.

   If any other change noted, was recorded.

5. After about two weeks of intensive work (early in morning and all day). noted something strange: All plants at high elevations had the very same chromoso e constitution: no knobs except a small one, homozygous, in long arm of chromosome 7. ~~Nexe~~ Two exceptions, and these proved to be very important for conclusions.
   In loser elevations, other knobs began to appear. Some were medium sized, some were large.
   In Ecuador, at low elevation, several races at an incredible number of very large knobs. Nearly all knob forming regions occuppied.

   Mangelsdorf theory:reason for my being in Peru and Colombia. The higher the elevation, the fewer knobs one would find.
   I began to wonder if Mangelsdorf might be right. Asked the maize man responsible for the maize work at Medellin, if he had any material from plants collected in the spur of the Andes that enters Venezuela. His answer, Yes, and he brought some to me.

   The Venezuealan highlands collections: Completely filled with very large knobs. The knobs, remain as distinct deep-staining roundish bodies in nuclei. The nuclei looked as if they were filled with marbles! Obviously, Mangelsdorf theory not working.

   Began to recognize that the knobs were conservative. Finished my period in Medellín and off to Bogatá to place collections on maps.

   To place each collection on a map of the country where collected took a week with excellent and enthusiastic cooperation with maize persons in Colombia, particularly Dave Timothy who became as excited as I about the results, as they were developing from the maps.
   Became clear that (1) knobs were very conservative. The Andean complex of small knob in chro osome 7 long arm, extended almost unaltered from Ecuador through Bolivia and Chile.
   The Venezuelan Complex extended along northern shore of Ecuador.

   The areas of hybridizations: Andean meeting Venezuelan or other complexes could be readily observed, geographically.

   My conclusion: Centers of origin of maize development: start w th one type. Its expansion, then introductions later, then hybridizations.
   Where were the centers? If we examined maize from all over the Americas, we should find these centers.

   Transmission of this concept to Wellhausen by Timothy. His enthusiastic response. Invitation to try my theory in Mexico.

VII. THE MEXICAN EXPERIENCE.

1. Summer, 1959 and winter 1959-1960 in Mexico, Chapingo in summer where plants grown; winter in Mexico city examing collected materials.
2. The races examined:

   Collections of the 25 races described in Wellhausen publication.
   Collections of some typical races from Guatemala, Honduras, El Salvadore, Nicarauga, Costa Rica, Panama, and the Carribbean islands

3. The blind method of examining, to avoid bias.
4. The analysis of the results. Exciting. Excellent confirmation of anticipations. Much of Wellhausens predictions of origins of the races confirmed.
5. Complexes : no knobs, small knobs, medium size knobs, and large knobs began to fall into place plus the mixtures, the introductions and their contributions within the new locations.
6. Subsequently, Longley and Kato. Extended materials of Guatemala and the Caribbean Islands, and Central America.
7. Decision to cover the Americas from material collected. Needed people to work on the chromosomes at different locations.
8. The decision, to train persons from Latin America at the North Carolina State University at Raleigh. Contract there with the Rockefeller foundations for maize work.had preceded.

VIII. THE RALEIGH EXPERIENCE.

1. Persons: two from Brazil, one from Argentina, one from Mexico.
2. In cooperation with faculty there and with William L. Brown training program advanced. Degrees given.
3. Two of the 4 worked out very well. Kato from Mexico, and Blumenschein from Brazil. Returned to their countries and started examining races, and collections made in Brazil and Venezuela to increase materials available.

IX. THE RESOLUTIONS OF RESULTS, YEARLY IN MEXICO CITY.

1. Meetings each year, for about 6 weeks, to examine and discuss mat information collected for year, and plan for that of coming year.
2. Gradual recognition of uniqueness of study and its effectiveness in interpreting the origin and migration of the races.
3. The final monograph: hundreds of tables and maps. Integrated for ready retrieval. Some of the conclusions will follow after a few examoles are given of mode of operation.of this study.

X. THE OVERALL STUDY.

1. Where collections made. North and South America. SLIDES 11 and 12.
2. Some examples showing how the study integrates relationships: Importance of special knobs with very limited distributions. Will show a few of them here to indicate methods used.
3. EXAMPLES:

   (1). SLIDE 13. 10, long arm. position 1. Zapalote, Tepecintle. Guatemala highlands. Introduction to highlands south.

(2) SLIDE 14. 4 shart arm. Large and Medium. Coastal.

(3) SLIDE 15. 7 short arm; Large knob. Nal-Tel, Zapalote Coastal, Arc in Guatemala, Venzuela. Perola, Guianas, Roraima. Panama, Coastal Trop. Flint-Tuson. Trinidad. Cuba.

(4). SLIDE 16. Central mesa, Mexico and So. west U.S. 1 long arm, large and medium knob. Central Mesa dn highlands of Guatemala. Central Mesa and north and north west (Cónico germplasm, originally from Palomero Toluqueño.) Introductions in Central America.

(5). Chromosome 7 long arm. SLIDE 17. Small chromosome.

(6). SLIDE 18. 2 short arm, small knob. Guatemala to south. western Ven to Roraima. Highlands of Guatemala into Yucatan Highlands of Guatemala and Central Mesa. Central Mesa north through central region. South America: introcutions.

XI. GENERAL CONCLUSIONS.

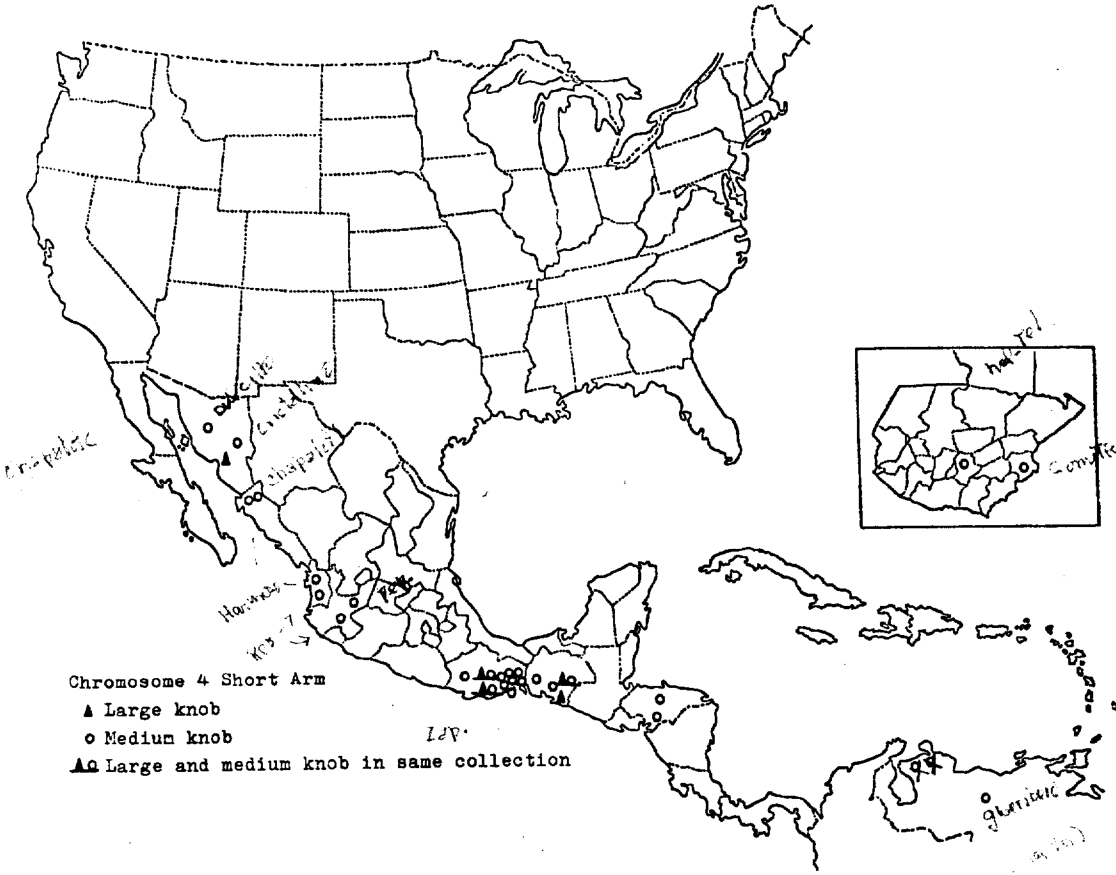
1. The centers: Knobless, Small knob, Large knobs, medium knob.
2. The integrations, the consequences for races, the migrations, the introductions, the consequences .
3. The land and see travels demonstrated.
4. The anthropomorphical implications: Maya maize origins, Andean maize origins and timing. Timing of introductions into Andes Mexico for distinctive pop corn. Venezuela much later (Colombia, adj. prob.
5. The origin of the various knob types, originally: Mexican Teosinte.

XII. The teosinte contribution to chromosome constitutions of maize and probably to its origin, and certainly to its germplasm subsequently to early selections. SLIDES 19, 20, 21.
The Indian tribes as plant breeders.

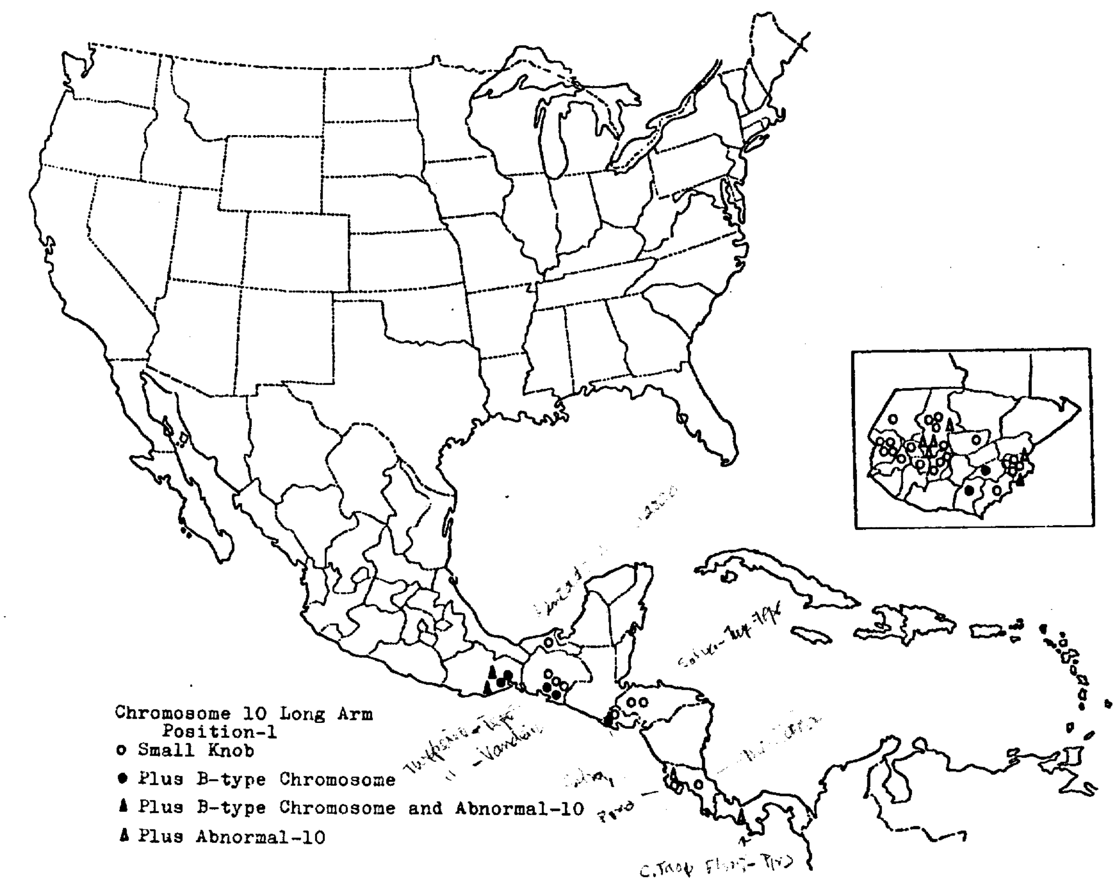
SLIDES

1. MAP of the Americas, Weatherwax maize distribution in "ancient" times.
2. COLOR. Commercial maize; mosaic pericarp. Purple aleurone.
3. COLOR. P^{vv}. Sector of "dark crown" and dark pigmented cob.
4. Ears of races, differences. Mangelsdorf. Fig. 9.1
5. Ears, Wellhausen Fig. 36. Palomero Toluqueño, Cacahuacintle, Cónico and hybrid of parents.
6. MAP, Wellhausen Fig. 32. Distribution of Cónico in Mexico.
7. Pachytene chromosomes. Morgan photo.
8. " " . McC photo.
9. " " . Kato photos. Heterozygous knobs.
10. DIAGRAM, knob locations, 10 chromosomes of maize. Kato.
11. MAP. Collections made in North America.
12. " . Collections made in South America.
13. " . Distribution of 10 long arm small knob, position 1.
14. " . " " 4 short arm, large and medium knobs.
15. " . " " 7 short arm, large knob.
16. " . " " 1, long arm, large and medium knobs.
17. " . " " 7 long arm, small knob.
18. " . " " 2 short arm, small knob.
19. MAP. Mexican states. Wellhausen
20. Photo of Teosinte. Mangelsdorf Figure 3.4. Chalco Teosinte
21. Ears, Maize inbred x teosinte with parents.

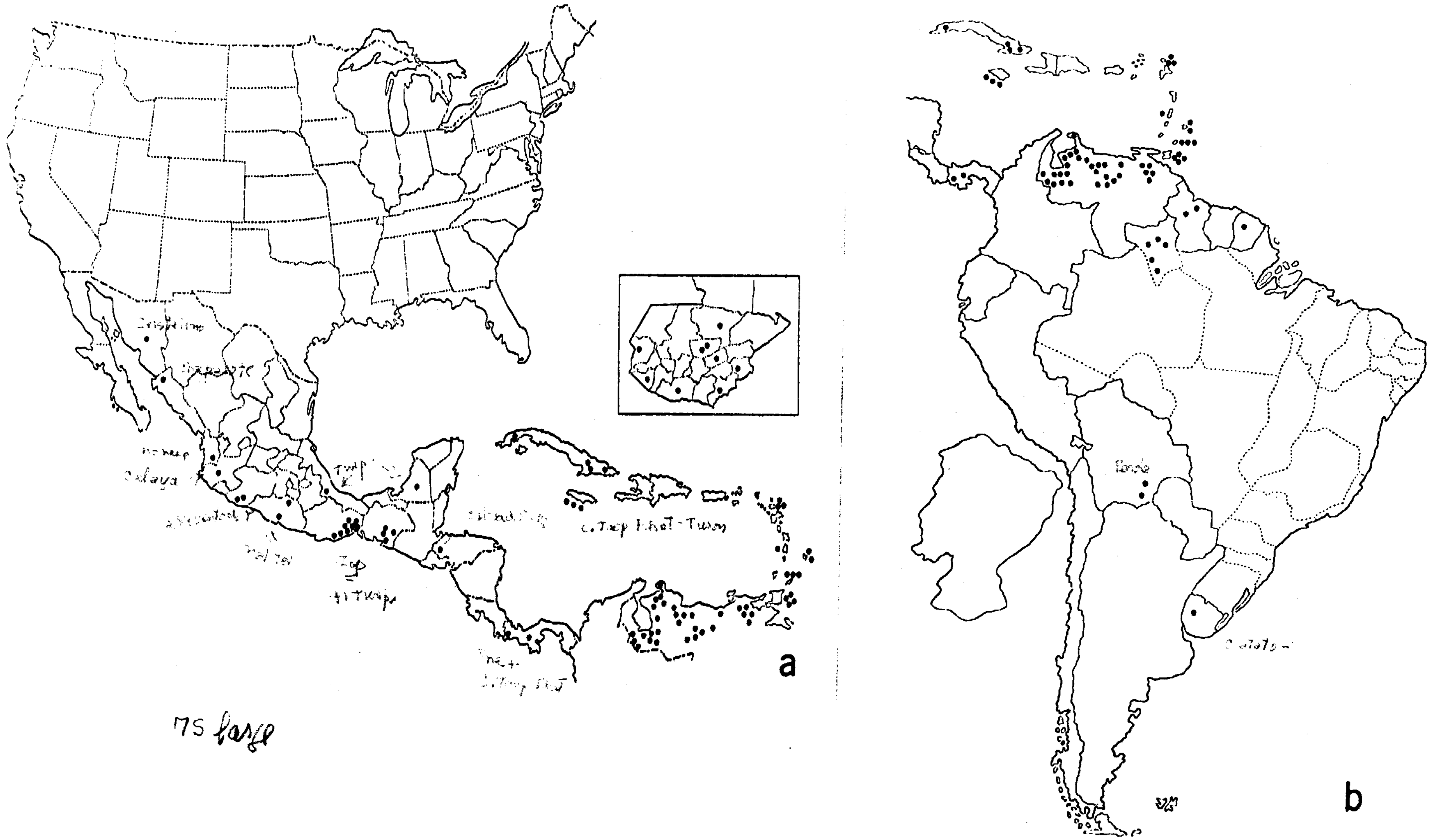
#14


Chromosome 4 Short Arm
▲ Large knob
o Medium knob
▲o Large and medium knob in same collection

#13


Chromosome 10 Long Arm
Position-1
o Small Knob
● Plus B-type Chromosome
▲ Plus B-type Chromosome and Abnormal-10
▲ Plus Abnormal-10

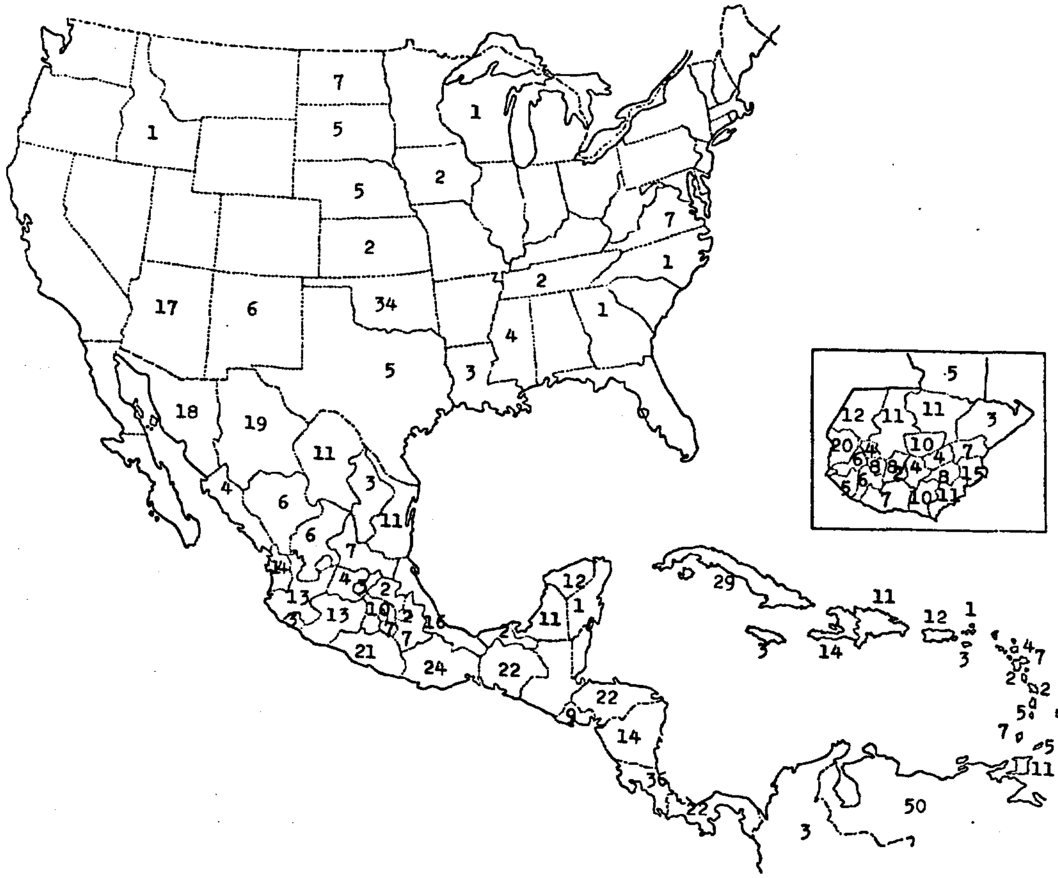
#15



a b

MS large

#11



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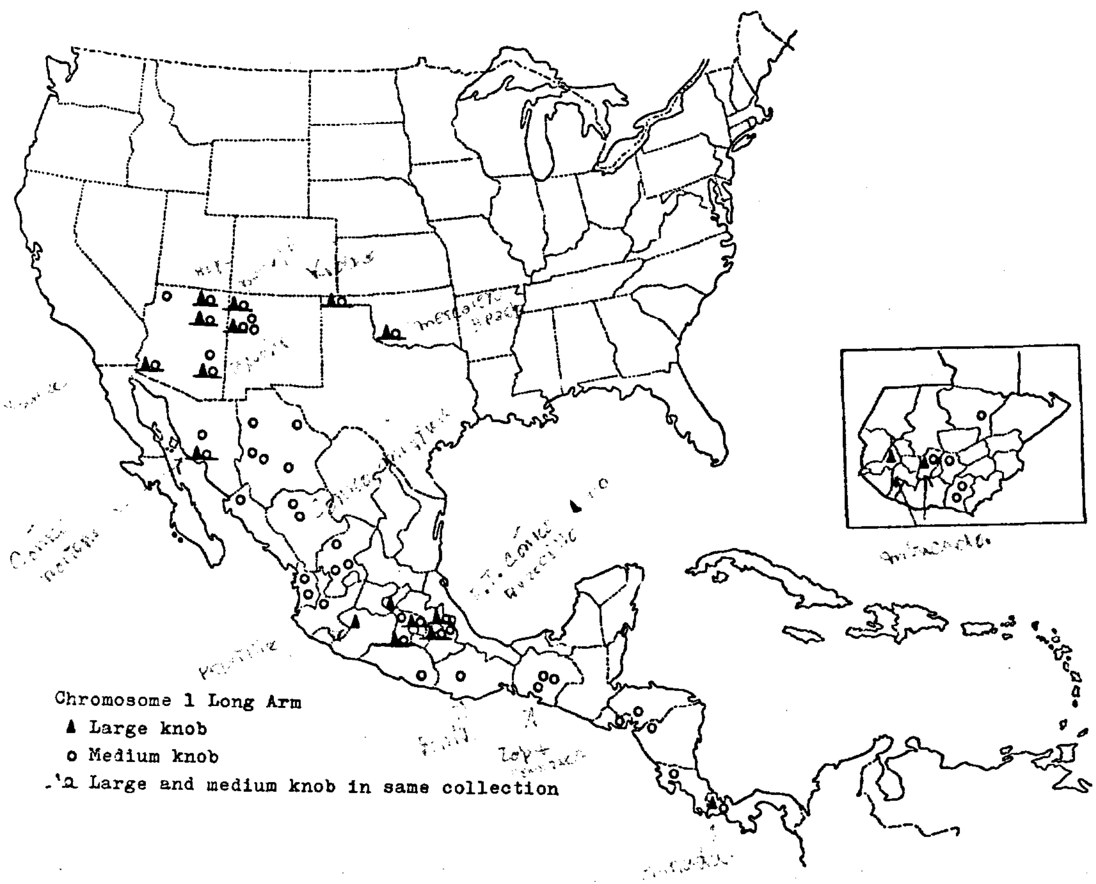
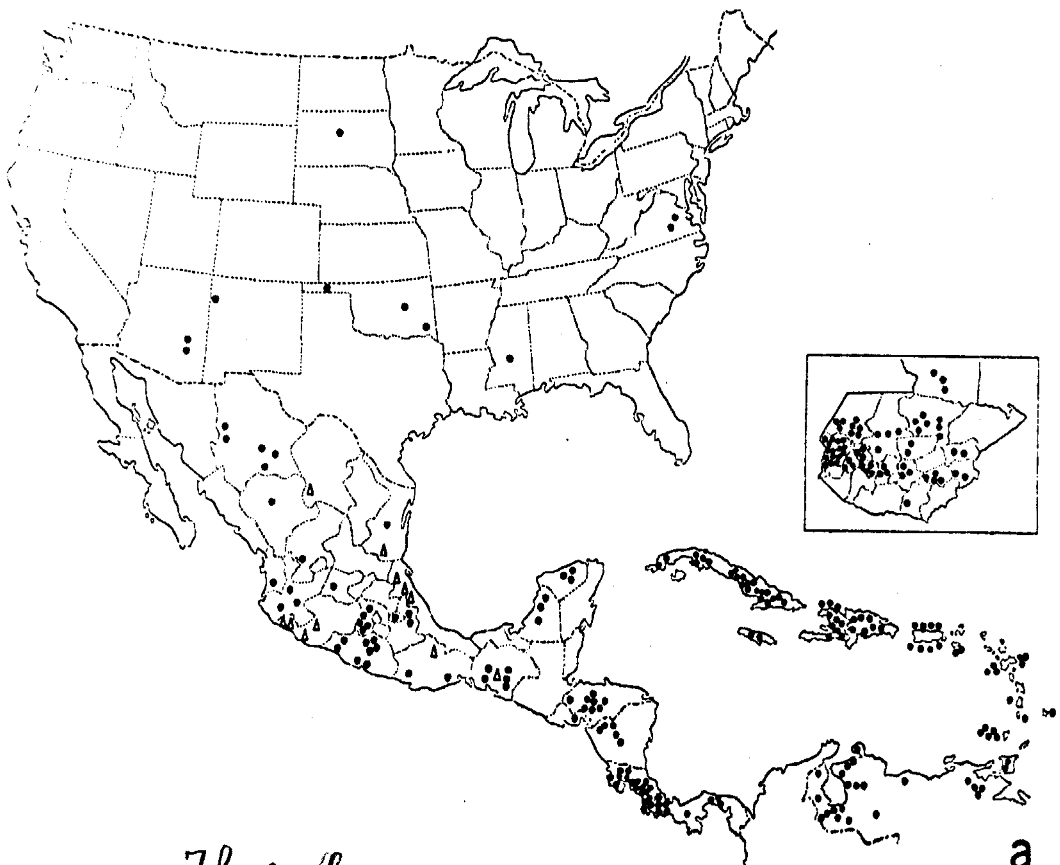
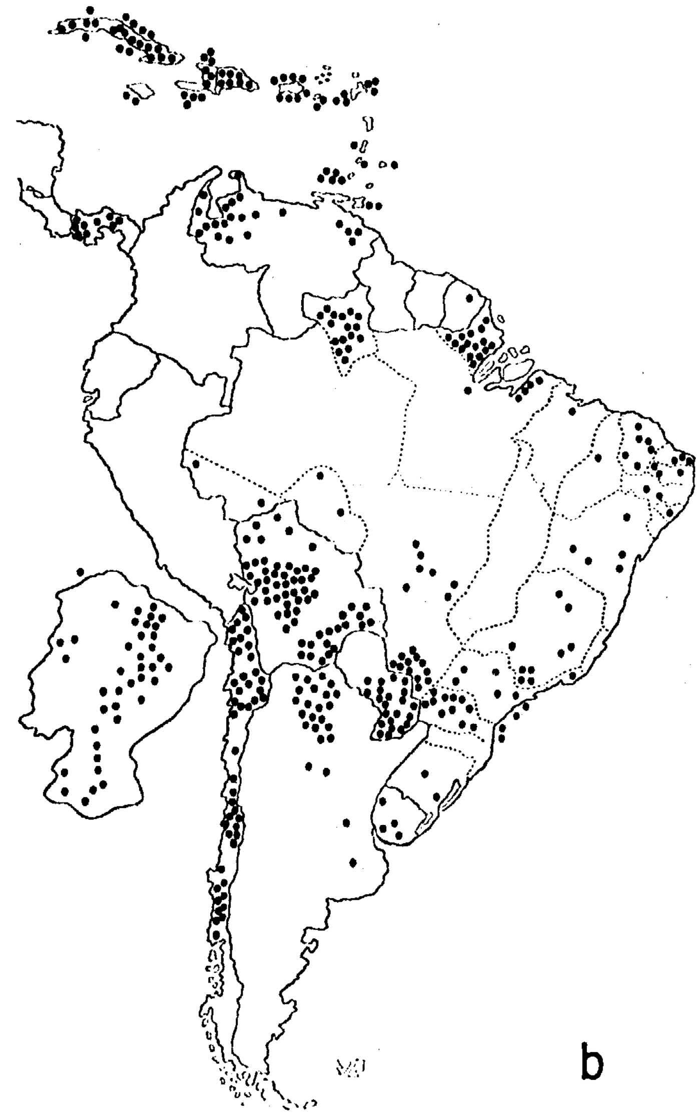

Chromosome 1 Long Arm
▲ Large knob
o Medium knob
▲o Large and medium knob in same collection

#17

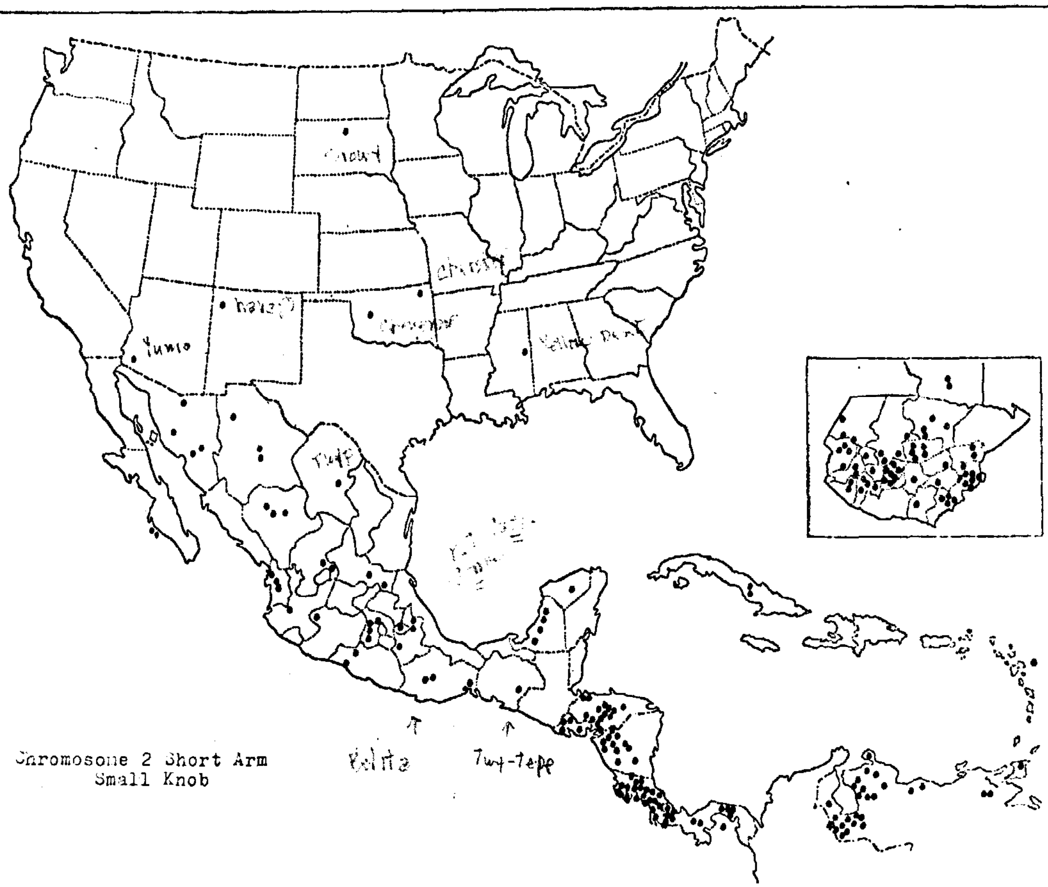


7l- small

a



b



Chromosome 2 Short Arm
Small Knob

Chromosome 2 Short Arm
Small Knob

#13