# Beyond the Black Box

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# Language, Individuals, Documents

- Speciation problem is also rampant in language
  - Language, Dialects, Idiolects
  - Dialect chains, Language families, Sprachbünde
  - Sociolects, Situational variation
- Practical solution: investigate **Doculects**
  - Documented (“docu”) language variant (“lect”)

# Phonemic Diversity Supports a Serial Founder Effect Model of Language Expansion from Africa

Quentin D. Atkinson[1,2]*

Human genetic and phenotypic diversity declines with distance from Africa, as predicted by a serial founder effect in which successive population bottlenecks during range expansion progressively reduce diversity, underpinning support for an African origin of modern humans. Recent work suggests that a similar founder effect may operate on human culture and language. Here I show that the number of phonemes used in a global sample of 504 languages is also clinal and fits a serial founder–effect model of expansion from an inferred origin in Africa. This result, which is not explained by more recent demographic history, local language diversity, or statistical non-independence within language families, points to parallel mechanisms shaping genetic and linguistic diversity and supports an African origin of modern human languages.

The number of phonemes—perceptually distinct units of sound that differentiate words—in a language is positively correlated with the size of its speaker population (*1*) in such a way that small populations have fewer phonemes. Languages continually gain and lose phonemes because of stochastic processes (*2*, *3*). If phoneme distinctions are more likely to be lost in small founder populations, then a succession of founder events during range expansion should progressively reduce phonemic diversity with increasing distance from the point of origin, paralleling the serial founder effect observed in population genetics (*4*–*9*). A founder effect has already been used to explain patterns of variation in other cultural replicators, including human material culture (*10*–*13*) and birdsong (*14*). A range of possible mechanisms (*15*) predicts similar dynamics governing the evolution of phonemes (*11*, *16*) and language generally (*17*–*20*). This raises the possibility that the serial founder–effect model used to trace our genetic origins to a recent expansion from Africa (*4*–*9*) could also be applied to global phonemic diversity to investigate the origin and expansion of modern human languages. Here I examine geographic variation in phoneme inventory size using data on vowel, consonant, and tone inventories taken from 504 languages in the World Atlas of Language Structures (WALS) (*21*), together with information on language location, taxonomic affiliation, and speaker demography (Fig. 1 and table S1) (*15*).

Consistent with previous work (*1*), speaker population size is a significant predictor of phonemic diversity (Pearson's correlation $r = 0.385$, df = 503, $P < 0.001$), with smaller population size predicting smaller overall phoneme inventories (fig. S1A). The same relationship holds for vowel ($r = 0.378$, df = 503, $P < 0.001$) and tone ($r = 0.230$, df = 503, $P < 0.001$) inventories separately, with a weaker, though still significant, effect of population size on consonant diversity ($r = 0.131$, df = 503, $P = 0.003$). To account for any non-independence within language families, the analysis was repeated, first using mean values at the language family level (table S2) and then using a hierarchical linear regression framework to model nested dependencies in variation at the family, subfamily, and genus levels (*15*). These analyses confirm that, consistent with a founder effect model, smaller population size predicts reduced phoneme inventory size both between families (family-level analysis $r = 0.468$, df = 49, $P < 0.001$; fig. S1B) and within families, controlling for taxonomic affiliation {hierarchical linear model: fixed-effect coefficient (β) = 0.0338 to 0.0985 [95% highest posterior density (HPD)], $P = 0.009$}.

Figure 1B shows clear regional differences in phonemic diversity, with the largest phoneme inventories in Africa and the smallest in South America and Oceania. A series of linear regressions was used to predict phoneme inventory size from the log of speaker population size and distance from 2560 potential origin locations around the world (*15*). Incorporating modern speaker population size into the model controls for geographic patterning in population size and means that the analysis is conservative about the amount of variation attributed to ancient demography. Model fit was evaluated with the Bayesian information criterion (BIC) (*22*). Following previous work (*5*, *6*), the set of origin locations within four BIC units of the best-fit location was taken to be the most likely area of origin under a serial founder–effect model.

The origin locations producing the strongest decline in phonemic diversity and best-fit model lie across central and southern Africa (Fig. 2A). This region could represent either a single origin for modern languages or the main origin under a polygenesis scenario. The best-fit model incorporating population size and distance from the origin explains 31% of the variance in phoneme inventory size [correlation coefficient ($R$) = 0.558, $F_{2,501} = 113.463$, $P < 0.001$] (Fig. 3). Both population size ($r_{population} = 0.146$, $P = 0.002$)

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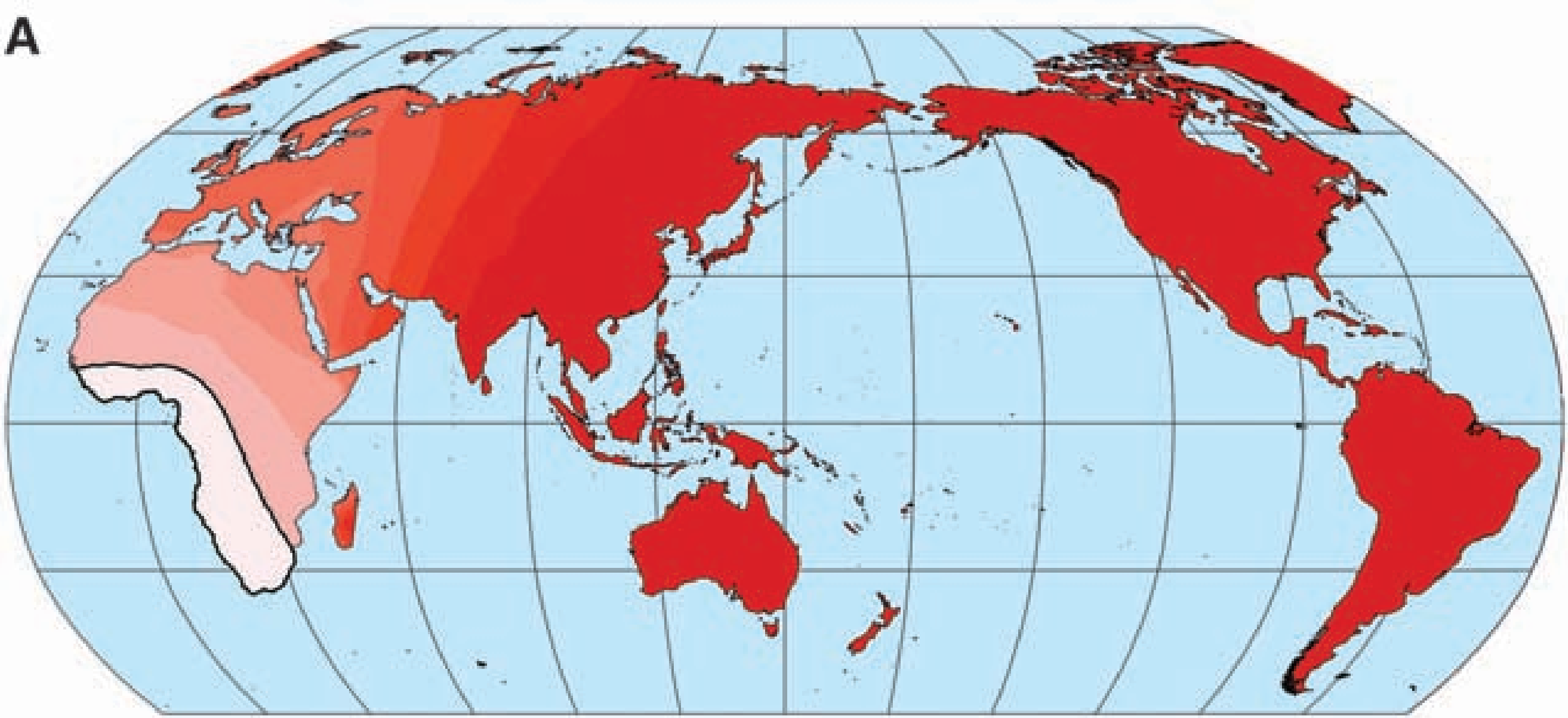
# Out-of-Africa Gradient



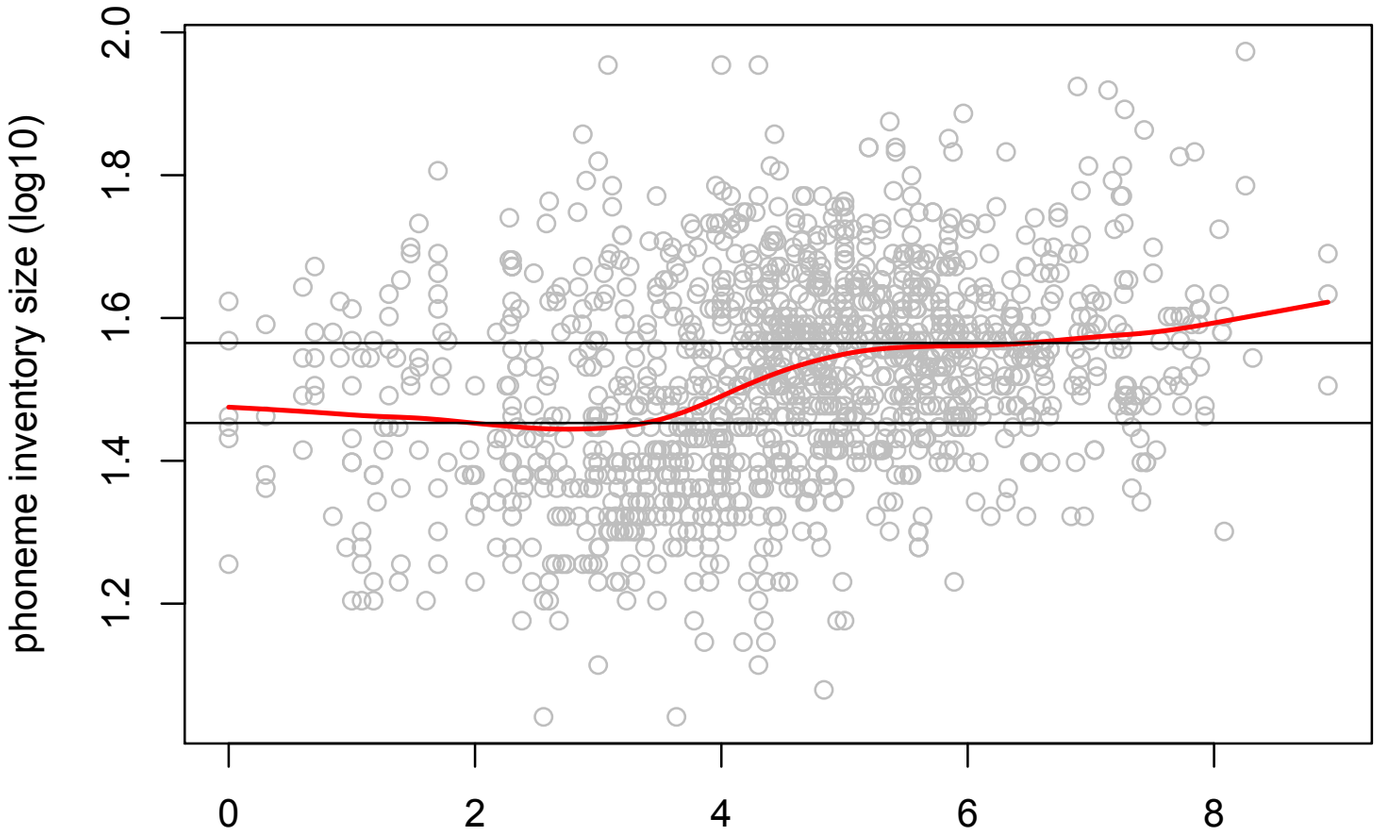

Atkinson, Quentin D. 2011. Phonemic Diversity Supports a Serial Founder Effect Model of Language Expansion from Africa. Science 332: 346-349.

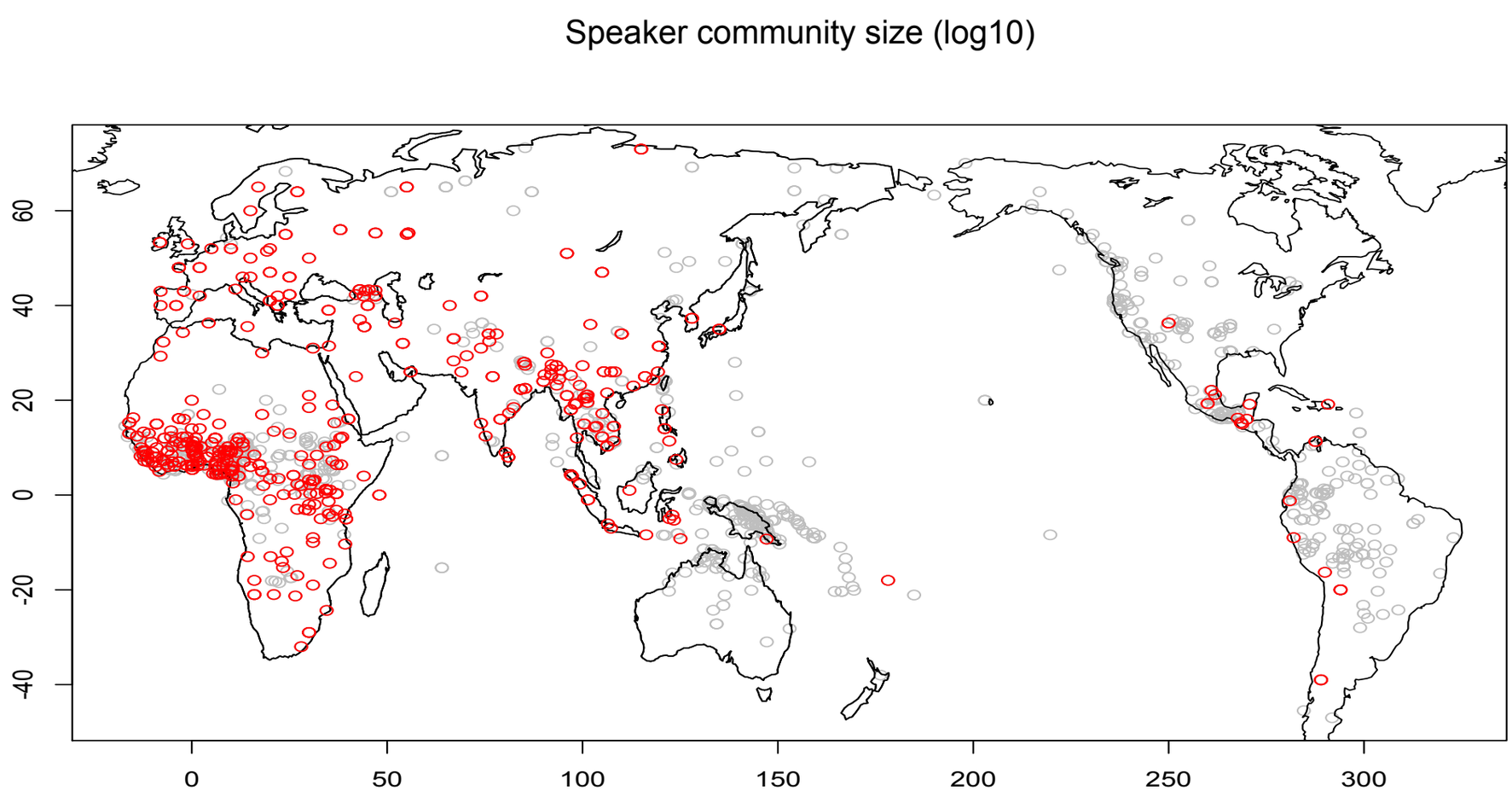
# Problems

- Based on three equally-weighted WALS features
  - Consonant Inventory
  - Vowel Quality Inventory
  - Tone Inventory

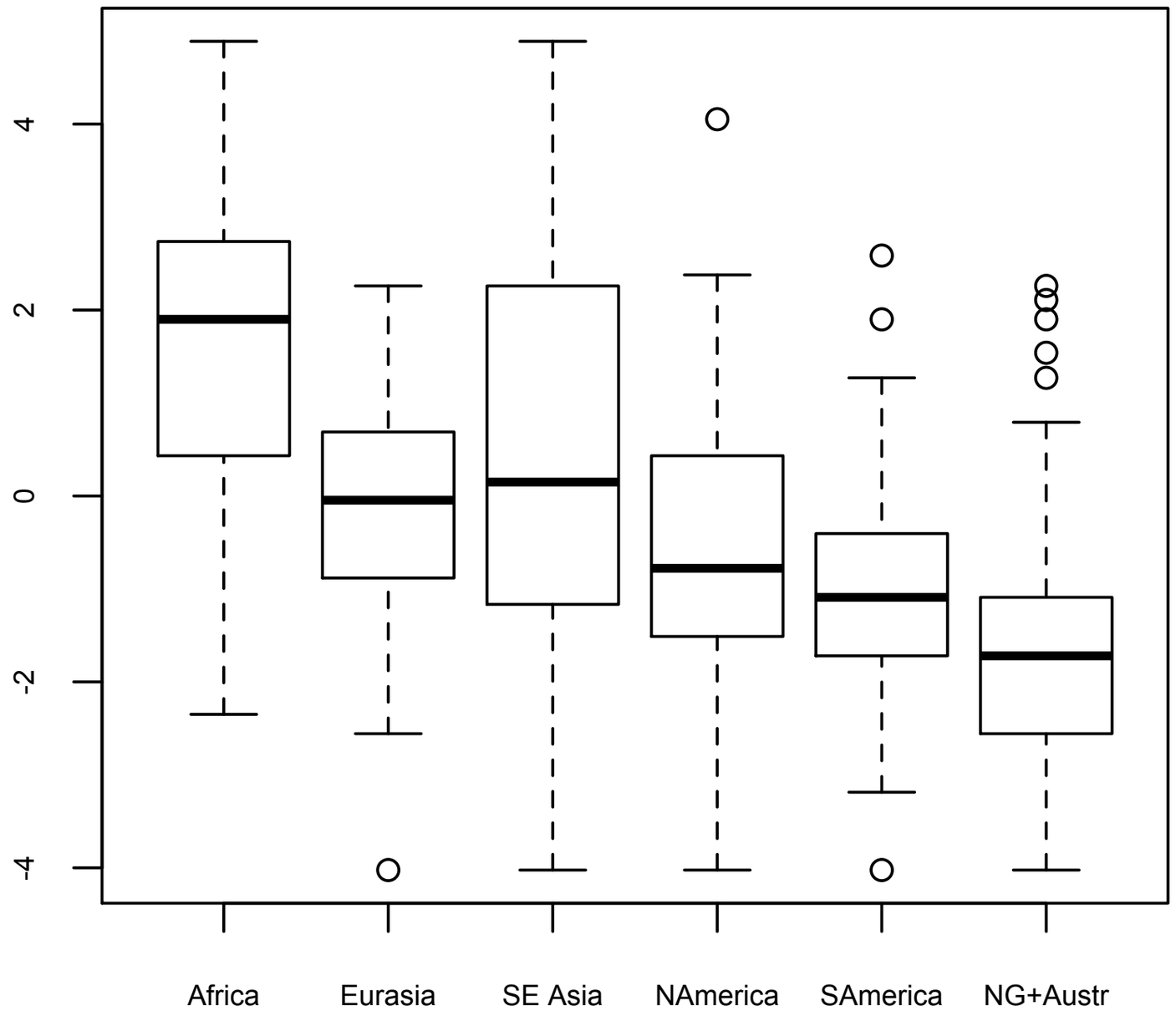
| *Mean* |
|---|
| 28 |
| 6 |
| ~1 |

- Correlation with speaker community size
- Simplistic geographical distance measurement

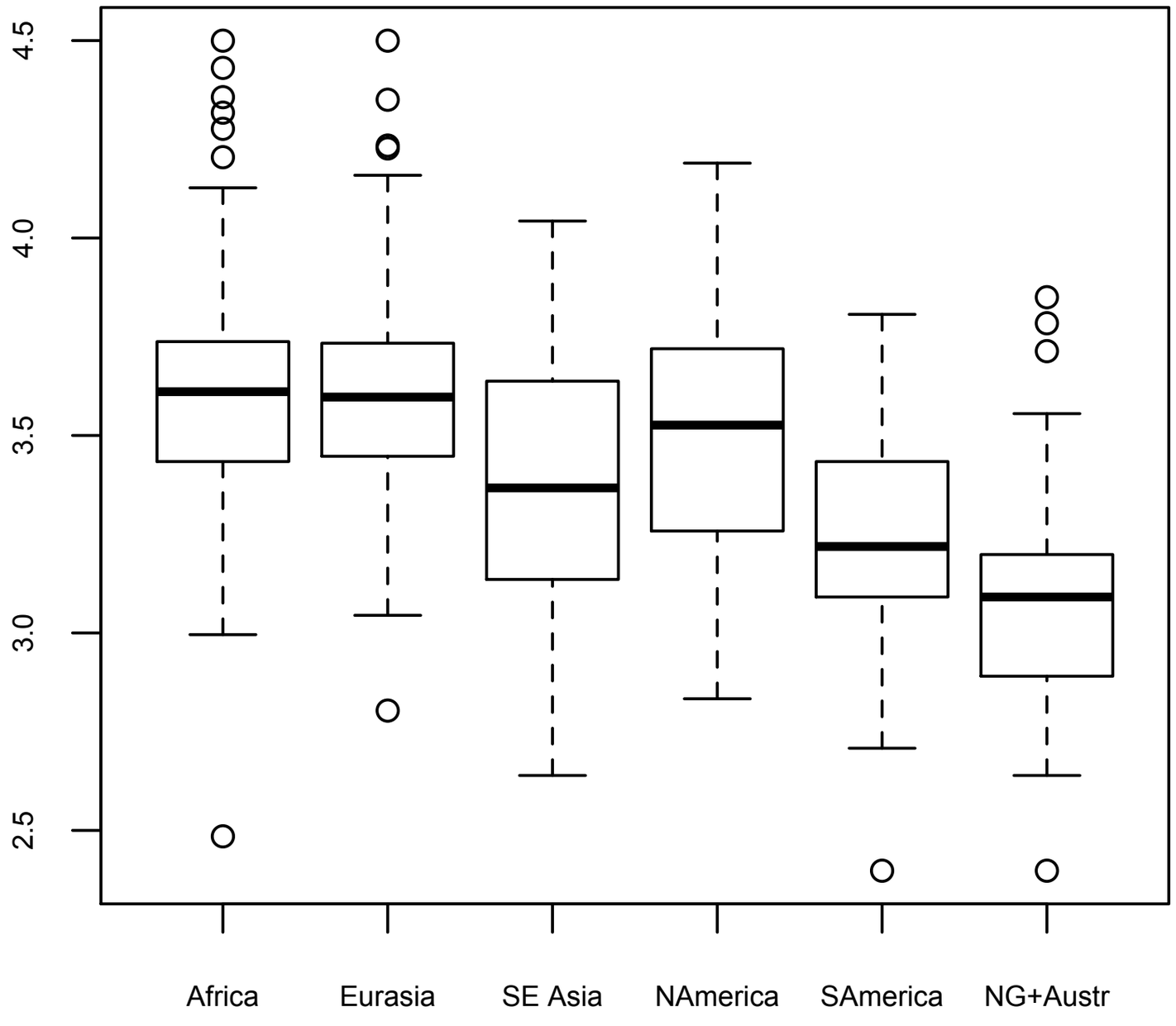

phoneme inventory size (log10)
1.2
1.4
1.6
1.8
2.0
0
2
4
6
8


Speaker community size (log10)
60
40
20
0
-20
-40
0
50
100
150
200
250
300

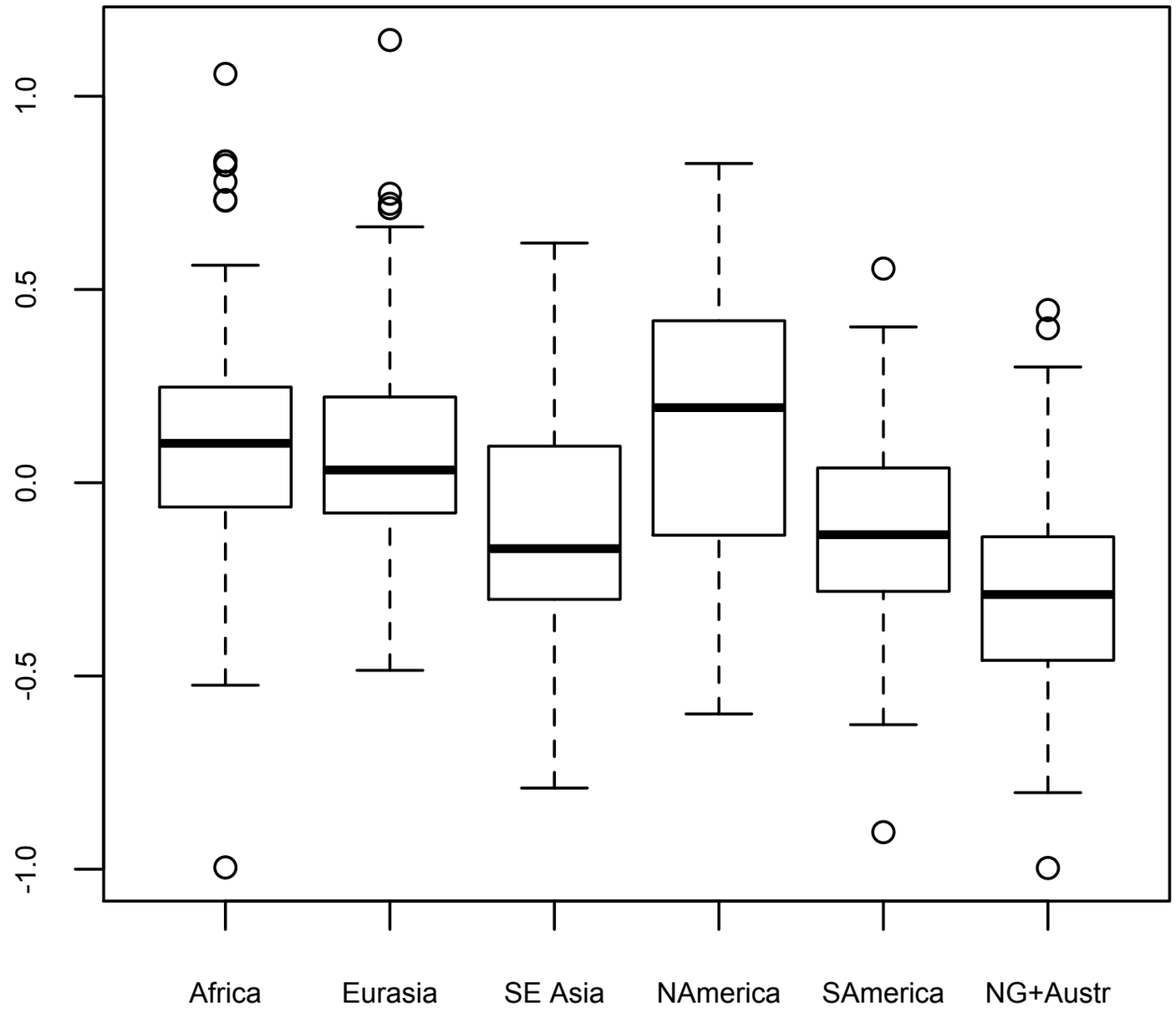
# Atkinson's Assessment of Inventories



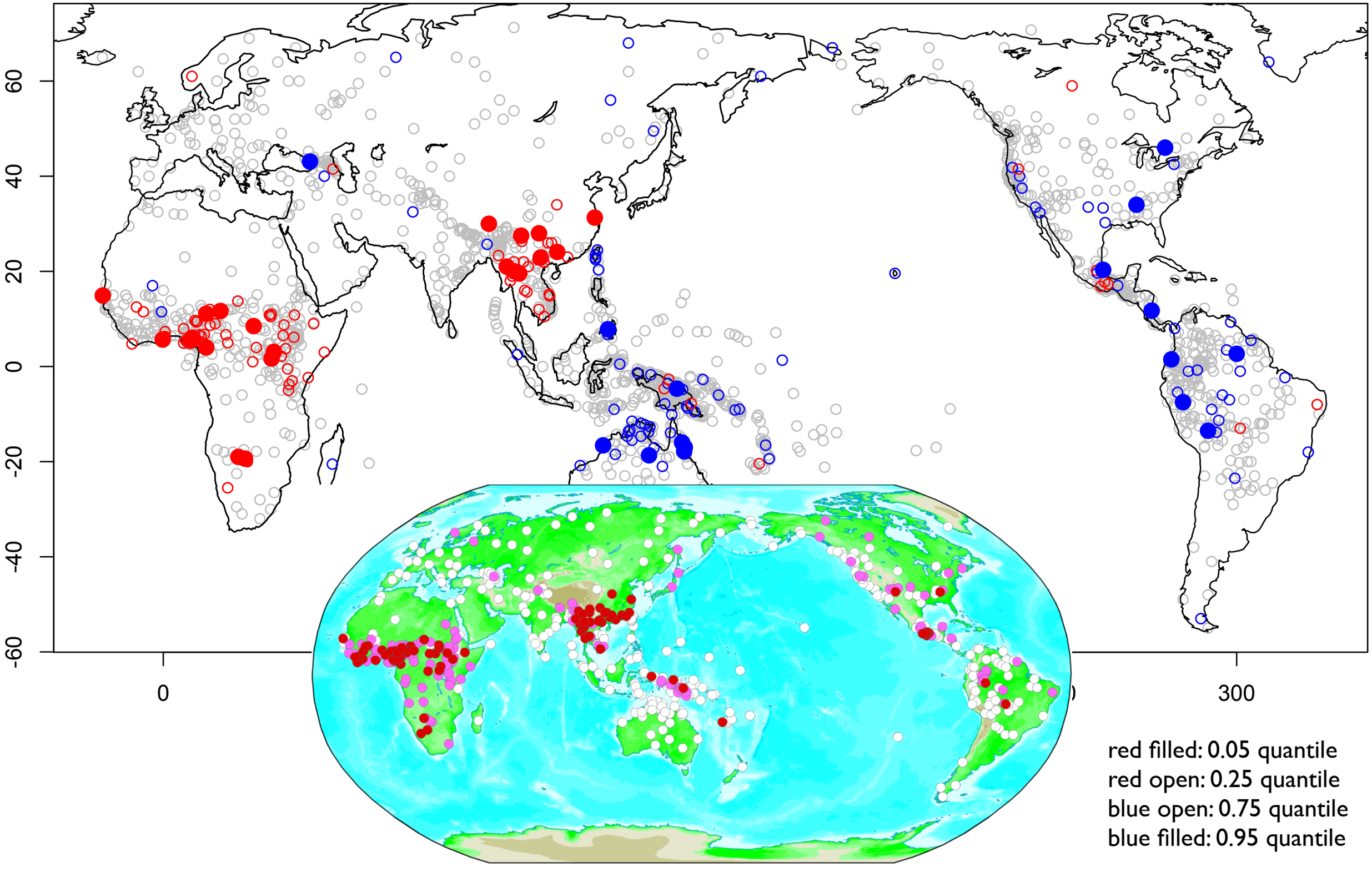
# Inventory Size from Phoible



# Residuals after Regression with Population Size

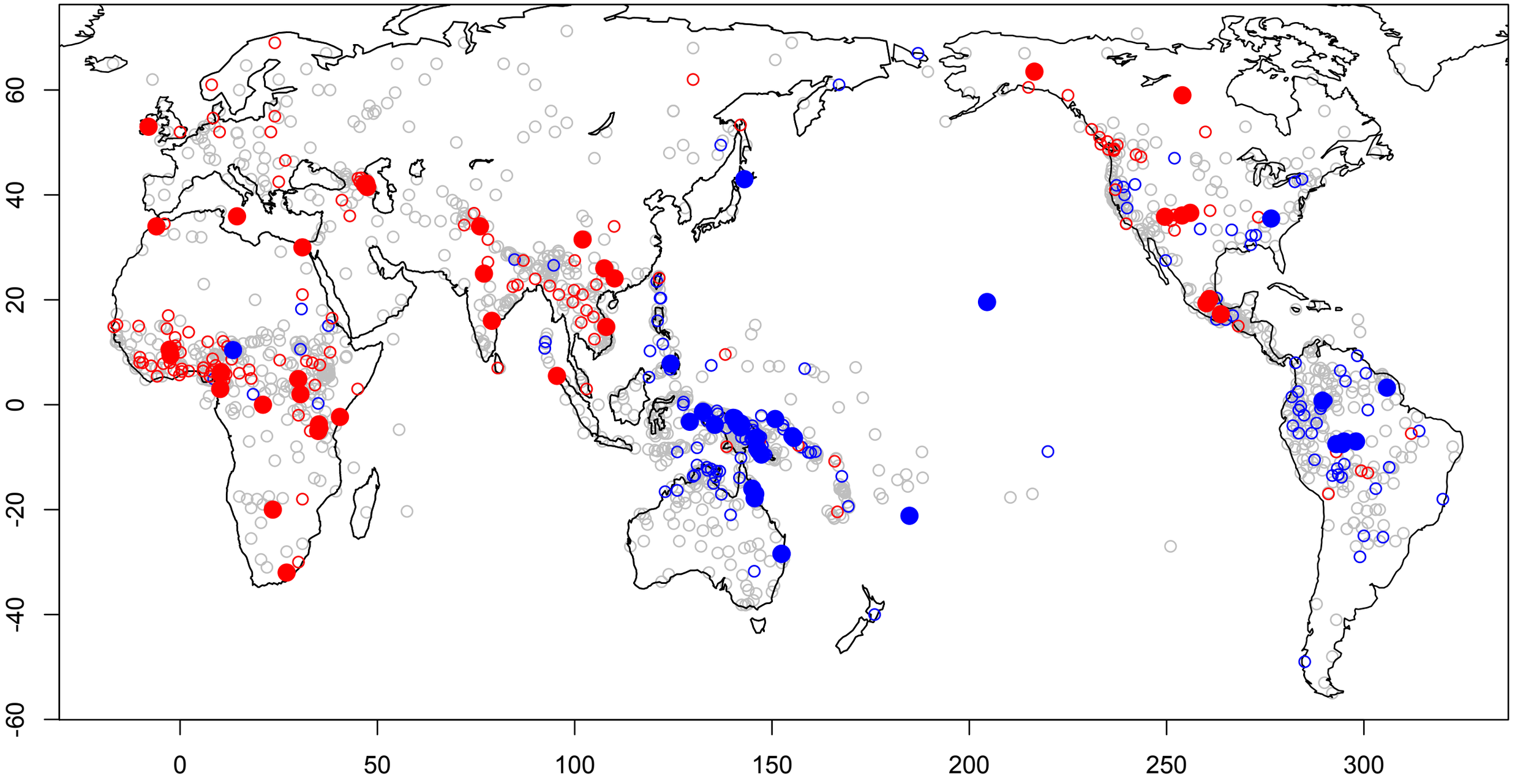


# Atkinson's Assessment of Inventories




red filled: 0.05 quantile
red open: 0.25 quantile
blue open: 0.75 quantile
blue filled: 0.95 quantile

# Inventory Size from Phoible




red filled: 0.05 quantile
red open: 0.25 quantile
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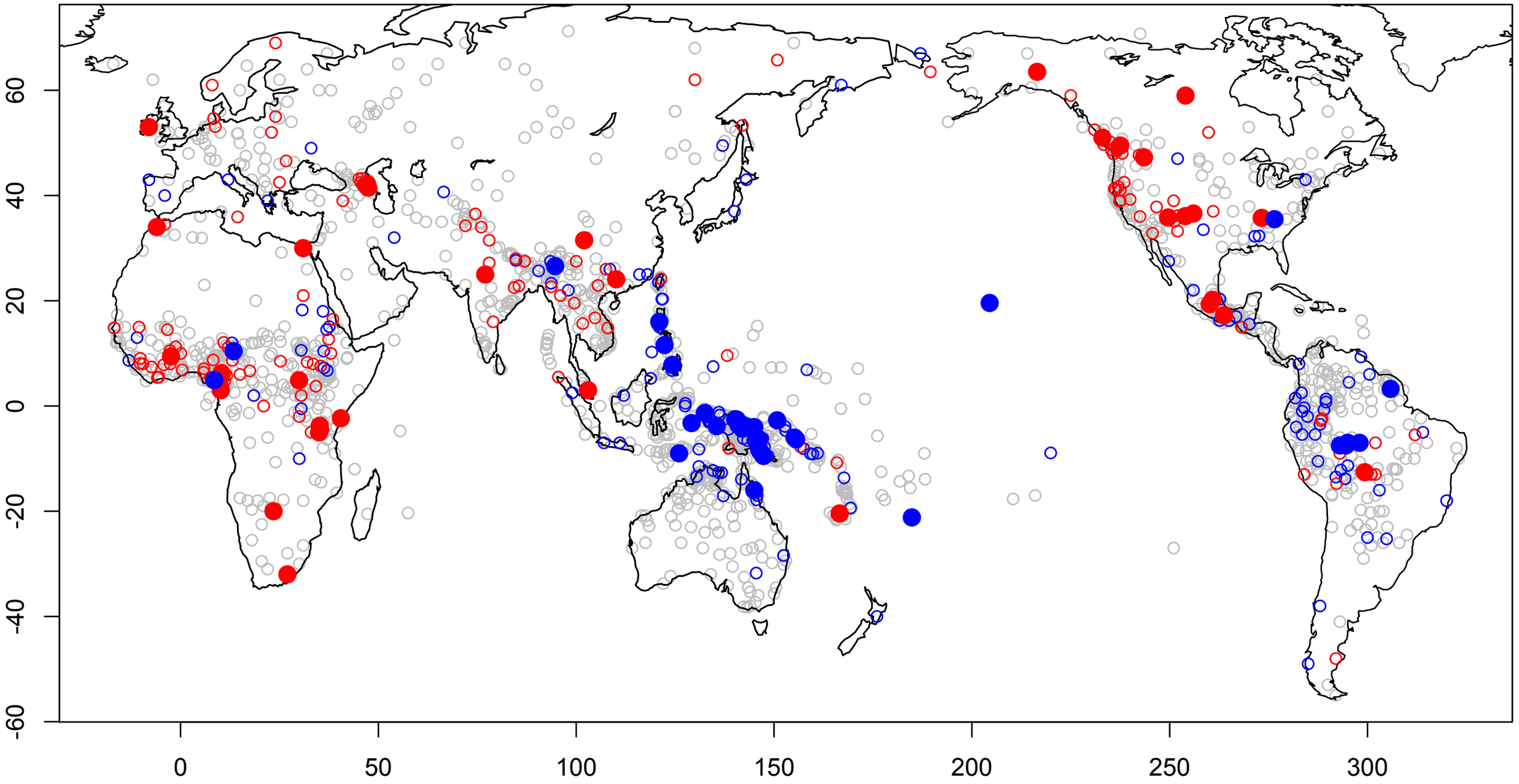
# Residuals after Regression with Population Size




red filled: 0.05 quantile
red open: 0.25 quantile
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# Beyond the Black Box

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# or:

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# Where is your model ?

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# ‘Black box’ comparisons

- Produce a tree without linguistic argumentation
- Based on written words
  - Possibly some form of orthographic normalization (e.g. IPA)
  - Levenshtein, n-grams, zipping
- Based on distribution of cognates over meanings
  - ‘Swadesh approach’
  - Depends on a priori cognate decisions
- Based on typological characteristics

Jivaroan

Panoan

Achuar

Shuar

Aguaruna

Matses

Cashibo

Shipibo

Amahuaca

Cashinahua

Sharanahua

Quechua_North-Junin

Quechua_Ambo-Pasco

Quechua_Huamalies-Dos-de-Mayo-Huanuco

Quechua_Margos-Yarowilca-Lauricocha

Quechua_Northern-Conchucos-Ancash

Quechua_Huaylas-Ancash

Quechua_Cajamarca

Quechua_Ayacucho

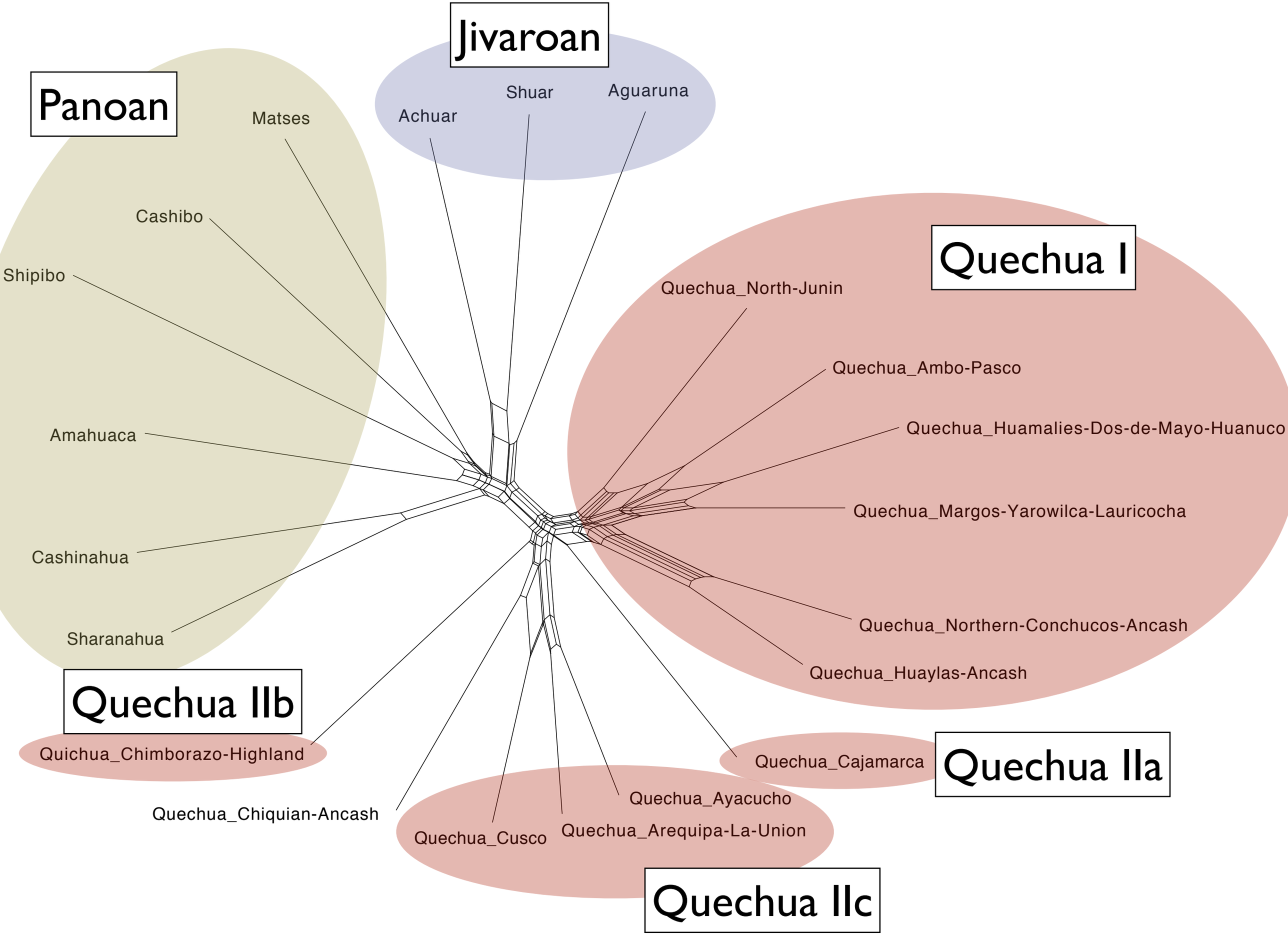
Quechua_Arequipa-La-Union

Quechua_Cusco

Quechua_Chiquian-Ancash

Quichua_Chimborazo-Highland

Quechua


Jivaroan
Achuar
Shuar
Aguaruna
Panoan
Matses
Cashibo
Shipibo
Amahuaca
Cashinahua
Sharanahua
Quechua I
Quechua_North-Junin
Quechua_Ambo-Pasco
Quechua_Huamalies-Dos-de-Mayo-Huanuco
Quechua_Margos-Yarowilca-Lauricocha
Quechua_Northern-Conchucos-Ancash
Quechua_Huaylas-Ancash
Quechua IIb
Quichua_Chimborazo-Highland
Quechua_Chiquian-Ancash
Quechua IIa
Quechua_Cajamarca
Quechua IIc
Quechua_Ayacucho
Quechua_Arequipa-La-Union
Quechua_Cusco

# The Problem

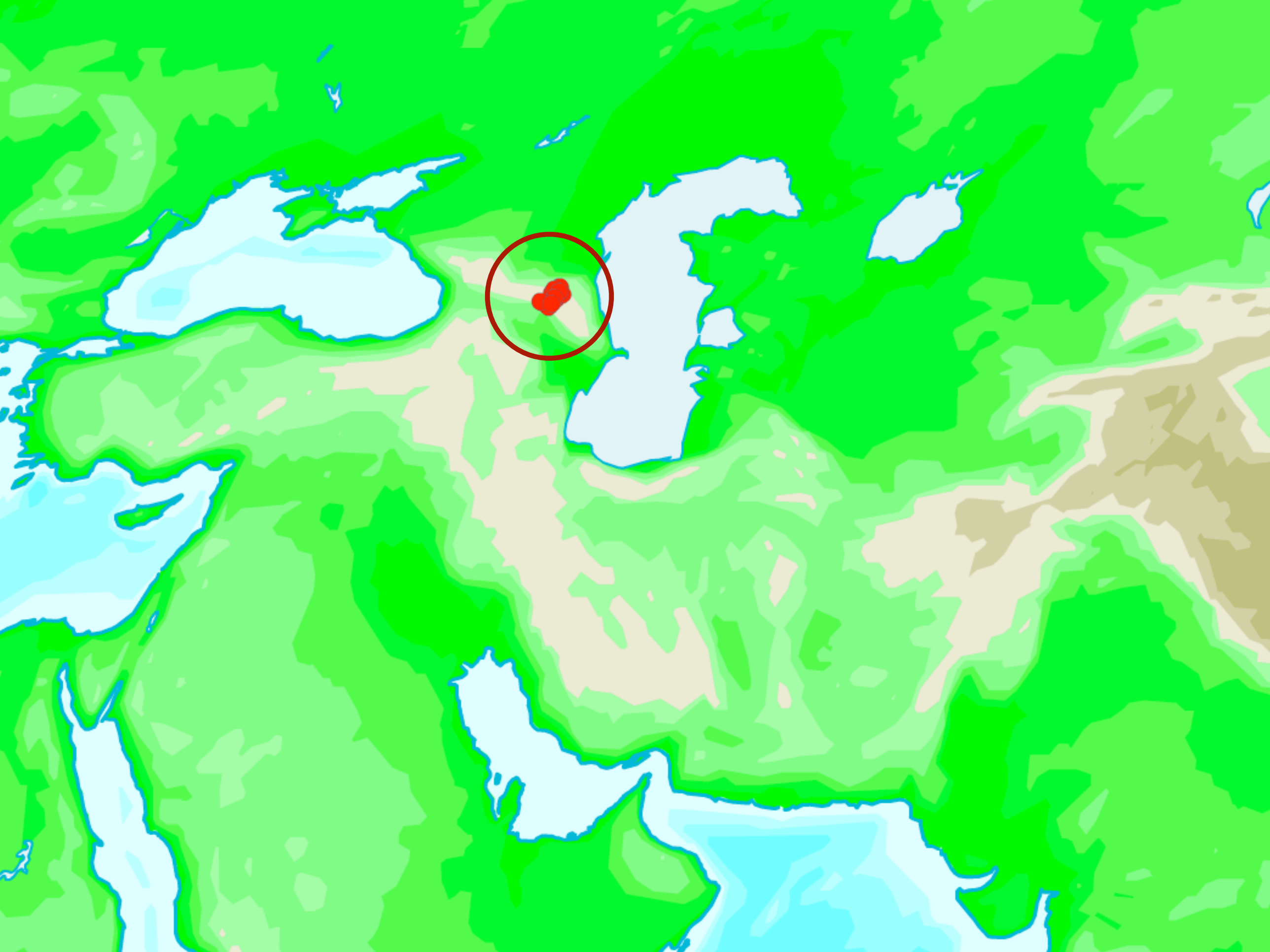
- New trees/networks do not help
  - There is no way to assess their value
  - why would a specialist believe one tree over another?
- Methodological education of linguists will still not convince them
  - Current quantitative methods have very limited grounding in linguistics
  - Quantitative model of language change is missing ("Dynamics")

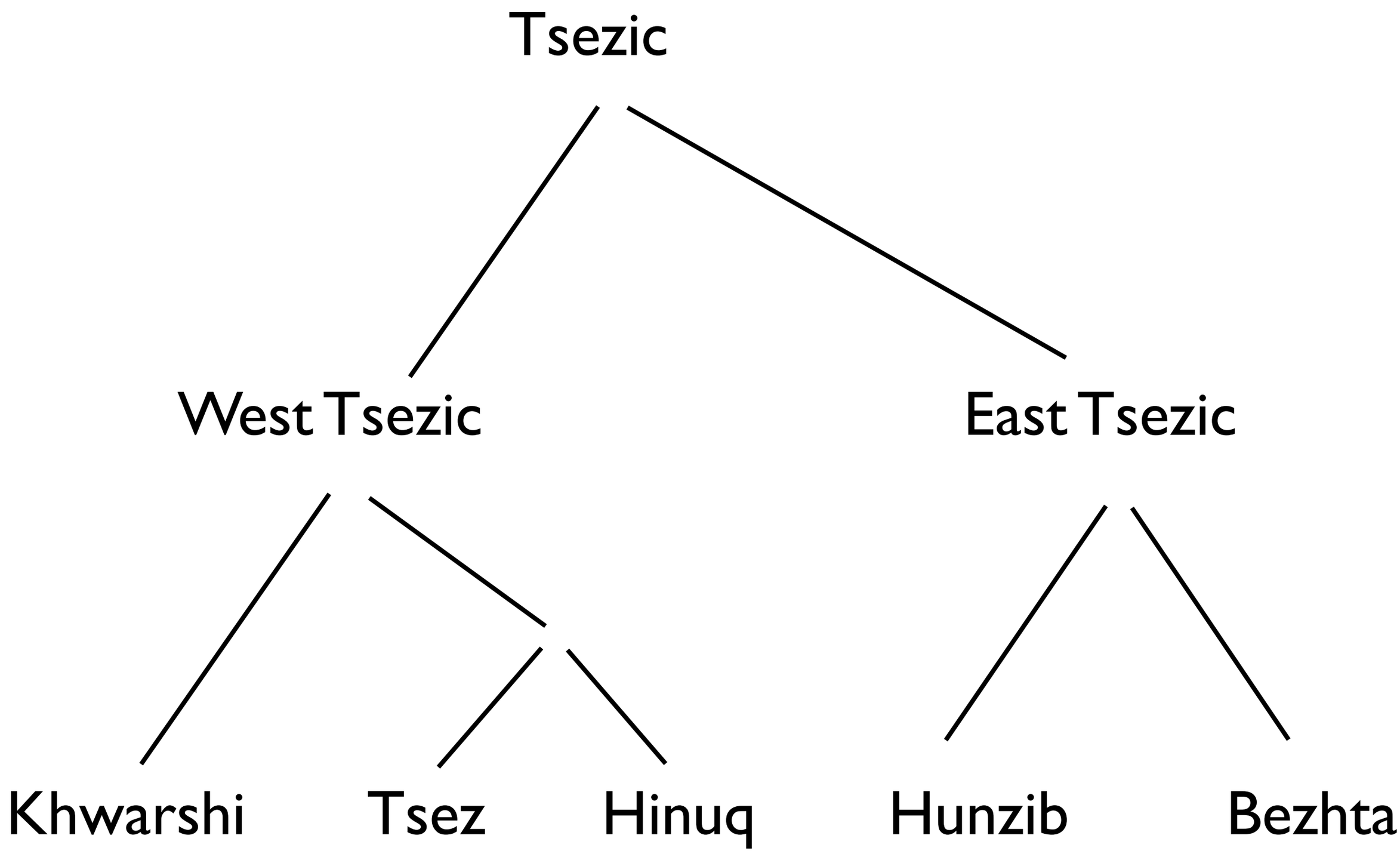
# Most Profitable Fields

- Report linguistically interpretable summary of proposed changes
  - cognate sets, sound changes
  - summarize changes that characterize subgroups
  - character methods preferred to distance methods
- Develop methods for linguistic specialist to ‘wade’ through the data
  - most specialist do all the work ‘by hand’
  - they strongly reduce data to keep it manageable
- Develop methods based on explicit language model

# Non-spatial usage of spatial case marking in Tsezic

(with Diana Forker)



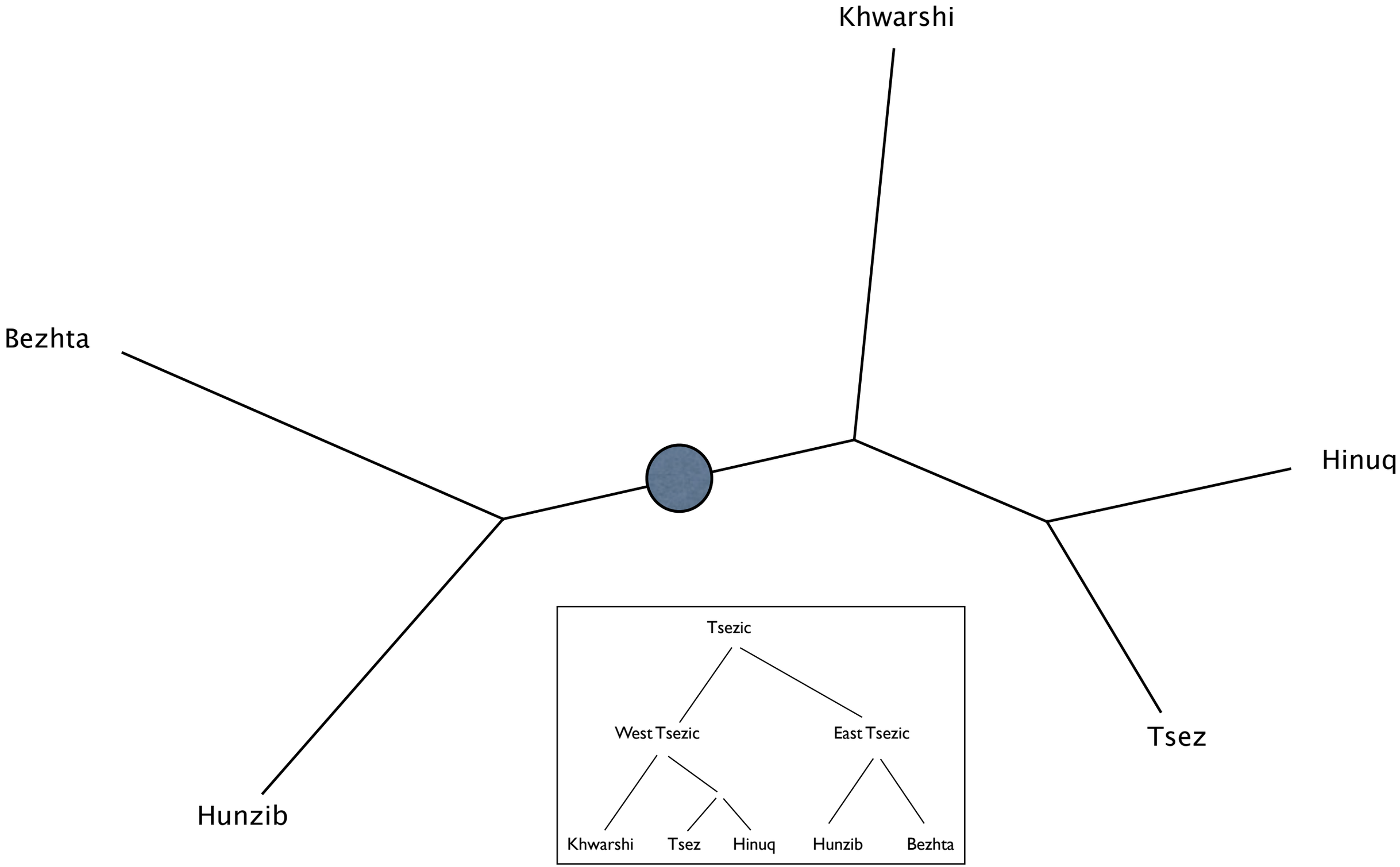

Tsezic
West Tsezic
East Tsezic
Khwarshi
Tsez
Hinuq
Hunzib
Bezhta

| Hinuq | CONT | IN | SUB | SPR | AT | APUD | AD | |
|---|---|---|---|---|---|---|---|---|
| Essive | -ł | -V/ma | -ƛ | -ƛ’o | -qo | -de | -ho | |
| Lative | -ł-er | -V/ma-r | -ƛ-er | -ƛ’o-r | -qo-r | -de-r | -ho-r | |
| Ablative/Genitive | -ł-es | -V/ma-s | -ƛ-es | -ƛ’o-s | -qo-s | -de-s | -ho-s | |
| Ablative | -ł-ezo | -V/ma-zo | -ƛ-ezo | -ƛ’o-zo | -qo-zo | -de-zo | -ho-zo | |
| Directive | -ł-edo | -V/ma-do | -ƛ-edo | -ƛ’o-do | -qo-do | -de-do | -ho-do | |
| Tsez | CONT | IN | SUB | SPR | AT | APUD | AD | |
| Essive | -ł | -ā | -ƛ | -ƛ’(o) | -q(o) | -de | -x(o) | |
| Lative | -ł-er | -ā-r | -ƛ-er | -ƛ’o-r | -qo-r | -de-r | -xo-r | |
| Ablative | -ł-āy | -ā-y | -ƛ-āy | -ƛ’-āy | -q-āy | -d-āy | -x-āy | |
| Versative | -ł-xor | -ā-ɣor | -ƛ-xor | -ƛ’-āɣor/’ār | -q-āɣor/ār | -d-āɣor/ār | -x-āɣor/ār | |
| Khwarshi | CONT | IN | SUB | SPR | AT | | AD | NEAR |
| Essive | -ł | -(m)a | -ƛ | -ƛ’o | -qo | | -ho | -ɣo |
| Lative | -ł-ul | -(m)a-l | -ƛ-ul | -ƛ’o-l | -qo-l | | -ho-l | -ɣo-l |
| Ablative | -ł-zi | -(m)a-zi | -ƛ-zi | -ƛ’o-zi | -qo-zi | | -ho-zi | -ɣo-zi |
| Versative | -ł-ɣul | -(m)a-ɣul | -ƛ-ɣul | -ƛ’o-ɣul | -qo-ɣul | | -ho-ɣul | -ɣo-ɣul |
| Translative | -ł-ɣužaz | -(m)a-ɣužaz | -ƛ-ɣužaz | -ƛ’o-ɣužaz | -qo-ɣužaz | | -ho-ɣužaz | -ɣo-ɣužaz |
| Terminative | -ł-q’a | -(m)a-q’a | -ƛ-q’a | -ƛ’o-q’a | -qo-q’a | | -ho-q’a | -ɣo-q’a |
| Bezhta | CONT | IN | SUB | SPR | AT | APUD | | NEAR |
| Essive | -ł | -ʔ | -ƛ | -ƛ’a | -qa | -doy | | -ɣa |
| Lative | | -ʔ-il | | -ƛ’a-l | | -doy-l | | -ɣa-l |
| Ablative/Genitive | -ł-so | -ʔ-is | -ƛ-so | -ƛ’a-s | -qa-s | -doy-s | | -ɣa-s |
| Ablative | -ł-la | -ʔ-la | -ƛ-la | -ƛ’a-la | -qa-la | -doy-la | | -ɣa-la |
| Directive | -ł-daa | -ʔ-daa | -ƛ’a-la | -ƛ’a-daa | -qa-daa | -doy-da | | -ɣa-daa |
| Translative | -ł-laƛ’ā | -ʔ-(la)ƛ’ā | -qa-la | -ƛ’a-laƛ’ā | -qa-laƛ’ā | -doy- | | -ɣa-laƛ’ā |
| Hunzib | CONT | IN | SUB | SPR | AT | APUD | | |
| Essive | -ł | -V | -ƛ | -ƛ’(o) | -g(o) | -dər | | |
| Ablative/Genitive | -ł-sə | -V-s | | -ƛ’o-s | -go-s | -dər-sə | | |
| Translative | -ł-ƛ’i | -V-ƛ’ | | -ƛ’o-ƛ’ | | -dər-ƛ’i | | |
| Directive | -ł-do | -dα-α | | | | -dər-do | | |

| Role | Label | Construction |
|---|---|---|
| Addressees | TALK | talk *[to somebody]* |
| | TELL | tell *[to somebody]* |
| | SHOUT | shout *[at somebody]* |
| | SAY | say *[to somebody]* |
| | ASK | ask *[somebody]* |
| | BEG | beg *[somebody]* |
| | EXPLAIN | explain *[to somebody]* |
| | TEACH | teach *[to somebody]* |
| | ORDER | order *[somebody]* |
| Human objects | MARRY | marry *[a man]* |
| | FEAR | fear *[somebody]* |
| | BELIEVE | believe *[somebody]* |
| | LISTEN | listen *[to somebody]* |
| Recipients | GIVE (PERMANENTLY) | give X as a gift *[to somebody]* |
| | GIVE (TEMPORARILY) | give X to hold *[to somebody]* |
| | SHOW | show X *[to somebody]* |
| Possessors | INALIENABLE POSSESSION | *[somebody]* has a daughter |
| | ALIENABLE POSSESSION | *[somebody]* has money |
| Subjects | AGE | *[somebody]* is X years old |
| | NAME | *[somebody]* is called X |
| | FIND | *[somebody]* finds X |
| Objects | EXCHANGE | give X away *[for something else]* |
| | PURPOSE/GOAL | go with the goal to get *[something]* |
| | LOOK | look *[at something]* |
| | METAPHORICAL LOCATION | talk *[about something]* |
| Causees | CAUSATIVE | cause *[somebody]* to do X |
| Potential agents | POTENTIAL | *[somebody]* can do X |
| | ABLE | *[somebody]* is able to do X |
| Reasons | NATURAL FORCE | *[because of something]* X happened |
| Converbs | SIMULTANEOUS | *[while X happened]* … |
| | TERMINATIVE | *[until/before X happened]* … |
| | CAUSAL | *[because X happened]* … |
| | POSTERIOR | *[after X happened]*… |
| Time indications | TIME SPAN | something happened *[during period X]* |
| | TIME POINT | something happened *[at time X]* |

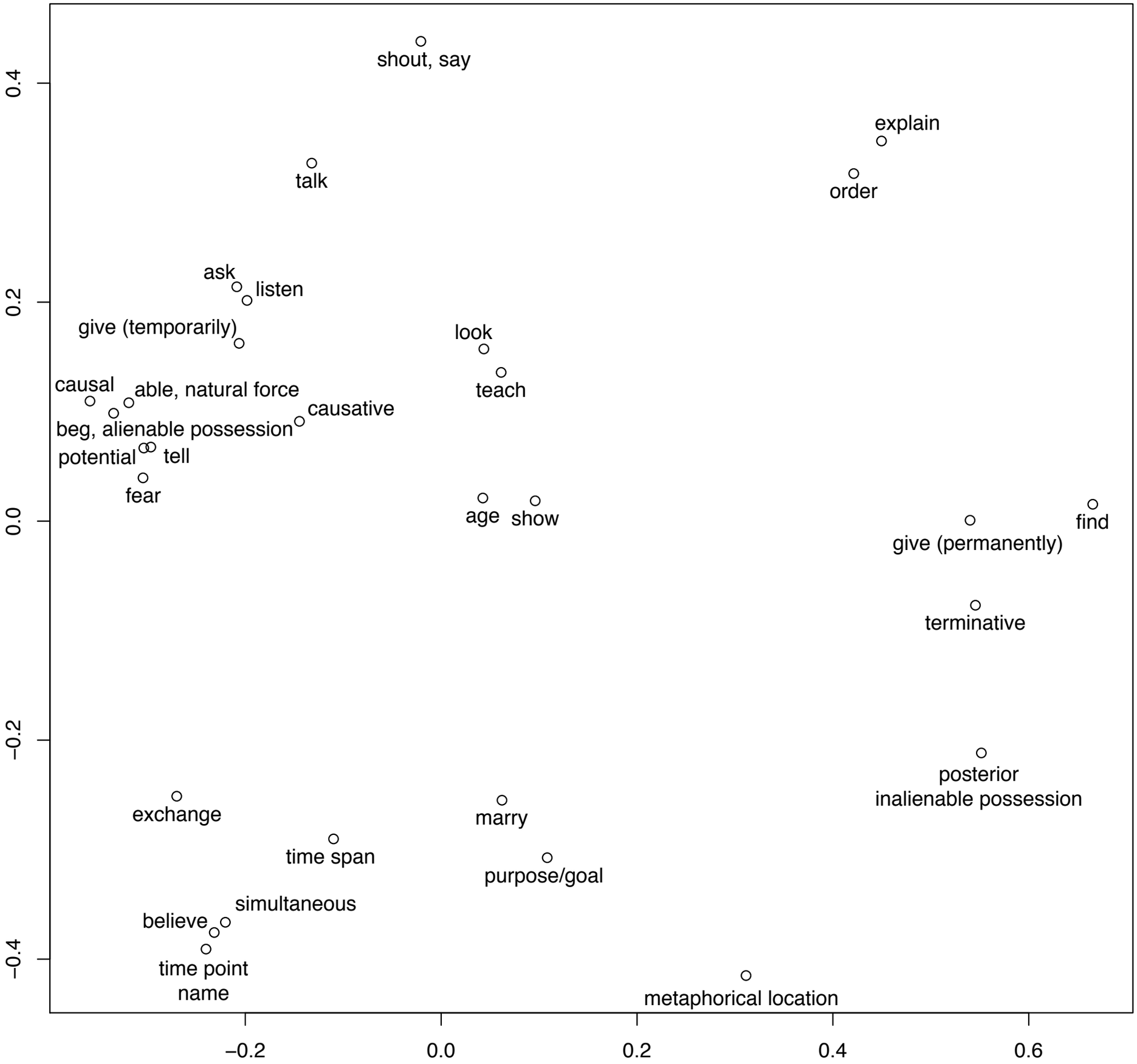
| Function | Hinuq | | Tsez | | Khwarshi | | Bezhta | | Hunzib | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Loc | Dir | Loc | Dir | Loc | Dir | Loc | Dir | Loc | Dir |
| able | AT | NULL | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| age | AT | NULL | AT | NULL | AT | NULL | NULL | LAT | NULL | GEN |
| alienable possession | AT | NULL | AT | NULL | AT | NULL | AT | NULL | – | – |
| ask | AT | NULL | AT | NULL | AT | LAT | AT | NULL | AT | NULL |
| beg | AT | NULL | AT | NULL | AT | NULL | AT | NULL | – | – |
| believe | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| causal | – | – | AT | NULL | – | – | AT | NULL | AT | NULL |
| causative | AT | NULL | AT | NULL | AT | NULL | NULL | INSTR | AT | NULL |
| exchange | SUB | NULL | SUB | NULL | SUB | NULL | SUB | NULL | SUB | NULL |
| explain | AT | LAT | NULL | LAT | AT | LAT | NULL | LAT | – | – |
| fear | AT | NULL | AT | NULL | AT | NULL | AT | NULL | SPR | NULL |
| find | NULL | DAT | NULL | LAT | NULL | LAT | NULL | LAT | – | – |
| give (permanently) | NULL | DAT | NULL | LAT | NULL | LAT | NULL | LAT | IN | NULL |
| give (temporarily) | AT | NULL | AT | NULL | NEAR | LAT | AT | NULL | AT | NULL |
| inalienable possession | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| listen | AT | NULL | AT | LAT | AT | NULL | AT | NULL | – | – |
| look | SPR | LAT | SPR | LAT | AT | LAT | AT | NULL | AT | NULL |
| marry | AD | NULL | AD | NULL | AD | NULL | NULL | LAT | IN | NULL |
| metaphorical location | SPR | NULL | CONT | ABL | NULL | GEN | NULL | GEN | SPR | GEN |
| name | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | – | – |
| natural force | AT | NULL | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| order | AT | LAT | AT | LAT | NULL | LAT | NULL | LAT | – | – |
| posterior | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| potential | AT | NULL | AT | NULL | AT | NULL | – | – | – | – |
| purpose/goal | SPR | NULL | SPR | LAT | AD | NULL | IN | LAT | SPR | NULL |
| say | AT | LAT | AT | LAT | AT | LAT | AT | NULL | AT | NULL |
| shout | AT | LAT | AT | LAT | AT | LAT | AT | NULL | AT | NULL |
| show | NULL | DAT | AT | NULL | AT | NULL | NULL | LAT | IN | NULL |
| simultaneous | SPR | NULL | SPR | NULL | SPR | NULL | IN | NULL | IN | NULL |
| talk | AT | LAT | AT | LAT | AT | NULL | AT | NULL | AT | NULL |
| teach | AT | NULL | AT | NULL | AT | LAT | NULL | LAT | IN | NULL |
| tell | AT | NULL | AT | NULL | AT | NULL | AT | NULL | IN | NULL |
| terminative | SPR | LAT | SPR | LAT | AD | LAT | NULL | LAT | NULL | LAT |
| time point | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | – | – |
| time span | CONT | NULL | CONT | NULL | NULL | INSTR | IN | NULL | CONT | NULL |

# Optimal maximum parsimony tree for case marking



| Functions | proto-Hinuq/Tsez | | proto-West Tsezic | | proto-East Tsezic | | proto-Tsezic | |
|---|---|---|---|---|---|---|---|---|
| | Loc | Dir | Loc | Dir | Loc | Dir | Loc | Dir |
| able | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| age | AT | NULL | AT | NULL | ***AT*** | ***NULL*** | ***AT*** | ***NULL*** |
| alienable possession | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| ask | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| beg | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| believe | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| causal | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| causative | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| exchange | SUB | NULL | SUB | NULL | SUB | NULL | SUB | NULL |
| explain | ***NULL*** | LAT | ***NULL*** | LAT | ***NULL*** | LAT | ***NULL*** | LAT |
| fear | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| find | NULL | LAT | NULL | LAT | NULL | LAT | NULL | LAT |
| give (permanently) | NULL | LAT | NULL | LAT | NULL | LAT | NULL | LAT |
| give (temporarily) | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| inalienable possession | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| listen | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| look | SPR | LAT | AT | LAT | AT | NULL | AT | ***NULL*** |
| marry | AD | NULL | AD | NULL | – | NULL | – | NULL |
| metaphorical location | – | – | ***NULL*** | GEN | ***NULL*** | GEN | ***NULL*** | GEN |
| name | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| natural force | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| order | AT | LAT | NULL | LAT | NULL | LAT | NULL | LAT |
| posterior | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| potential | AT | NULL | AT | NULL | – | – | AT | NULL |
| purpose/goal | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| say | AT | LAT | AT | LAT | AT | NULL | AT | ***NULL*** |
| shout | AT | LAT | AT | LAT | AT | NULL | AT | ***NULL*** |
| show | ***AT*** | NULL | ***AT*** | NULL | ***AT*** | NULL | ***AT*** | NULL |
| simultaneous | SPR | NULL | SPR | NULL | IN | NULL | – | NULL |
| talk | AT | LAT | AT | NULL | AT | NULL | AT | NULL |
| teach | AT | NULL | AT | ***NULL*** | – | ***NULL*** | – | ***NULL*** |
| tell | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| terminative | SPR | LAT | ***NULL*** | LAT | ***NULL*** | LAT | NULL | LAT |
| time point | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| time span | CONT | NULL | CONT | NULL | CONT | NULL | CONT | NULL |

| Function | Hinuq | | Tsez | | Khwarshi | | Bezhta | | Hunzib | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Loc | Dir | Loc | Dir | Loc | Dir | Loc | Dir | Loc | Dir |
| able | AT | NULL | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| age | AT | NULL | AT | NULL | AT | NULL | NULL | LAT | NULL | GEN |
| alienable possession | AT | NULL | AT | NULL | AT | NULL | AT | NULL | – | – |
| ask | AT | NULL | AT | NULL | AT | LAT | AT | NULL | AT | NULL |
| beg | AT | NULL | AT | NULL | AT | NULL | AT | NULL | – | – |
| believe | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL |
| causal | – | – | AT | NULL | – | – | AT | NULL | AT | NULL |
| causative | AT | NULL | AT | NULL | AT | NULL | NULL | INSTR | AT | NULL |
| exchange | SUB | NULL | SUB | NULL | SUB | NULL | SUB | NULL | SUB | NULL |
| explain | AT | LAT | NULL | LAT | AT | LAT | NULL | LAT | – | – |
| fear | AT | NULL | AT | NULL | AT | NULL | AT | NULL | SPR | NULL |
| find | NULL | DAT | NULL | LAT | NULL | LAT | NULL | LAT | – | – |
| give (permanently) | NULL | DAT | NULL | LAT | NULL | LAT | NULL | LAT | IN | NULL |
| give (temporarily) | AT | NULL | AT | NULL | NEAR | LAT | AT | NULL | AT | NULL |
| inalienable possession | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| listen | AT | NULL | AT | LAT | AT | NULL | AT | NULL | – | – |
| look | SPR | LAT | SPR | LAT | AT | LAT | AT | NULL | AT | NULL |
| marry | AD | NULL | AD | NULL | AD | NULL | NULL | LAT | IN | NULL |
| metaphorical location | SPR | NULL | CONT | ABL | NULL | GEN | NULL | GEN | SPR | GEN |
| name | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | – | – |
| natural force | AT | NULL | AT | NULL | AT | NULL | AT | NULL | AT | NULL |
| order | AT | LAT | AT | LAT | NULL | LAT | NULL | LAT | – | – |
| posterior | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN | NULL | GEN |
| potential | AT | NULL | AT | NULL | AT | NULL | – | – | – | – |
| purpose/goal | SPR | NULL | SPR | LAT | AD | NULL | IN | LAT | SPR | NULL |
| say | AT | LAT | AT | LAT | AT | LAT | AT | NULL | AT | NULL |
| shout | AT | LAT | AT | LAT | AT | LAT | AT | NULL | AT | NULL |
| show | NULL | DAT | AT | NULL | AT | NULL | NULL | LAT | IN | NULL |
| simultaneous | SPR | NULL | SPR | NULL | SPR | NULL | IN | NULL | IN | NULL |
| talk | AT | LAT | AT | LAT | AT | NULL | AT | NULL | AT | NULL |
| teach | AT | NULL | AT | NULL | AT | LAT | NULL | LAT | IN | NULL |
| tell | AT | NULL | AT | NULL | AT | NULL | AT | NULL | IN | NULL |
| terminative | SPR | LAT | SPR | LAT | AD | LAT | NULL | LAT | NULL | LAT |
| time point | SPR | NULL | SPR | NULL | SPR | NULL | SPR | NULL | – | – |
| time span | CONT | NULL | CONT | NULL | NULL | INSTR | IN | NULL | CONT | NULL |


shout, say
explain
talk
order
ask
listen
give (temporarily)
look
teach
causal
able, natural force
causative
beg, alienable possession
potential
tell
fear
age
show
find
give (permanently)
terminative
posterior
inalienable possession
exchange
marry
time span
purpose/goal
simultaneous
believe
time point
name
metaphorical location
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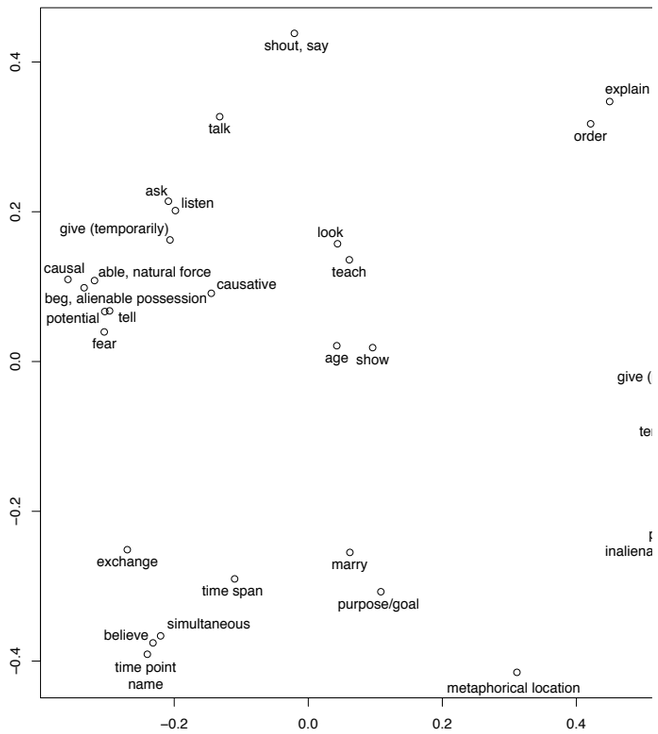
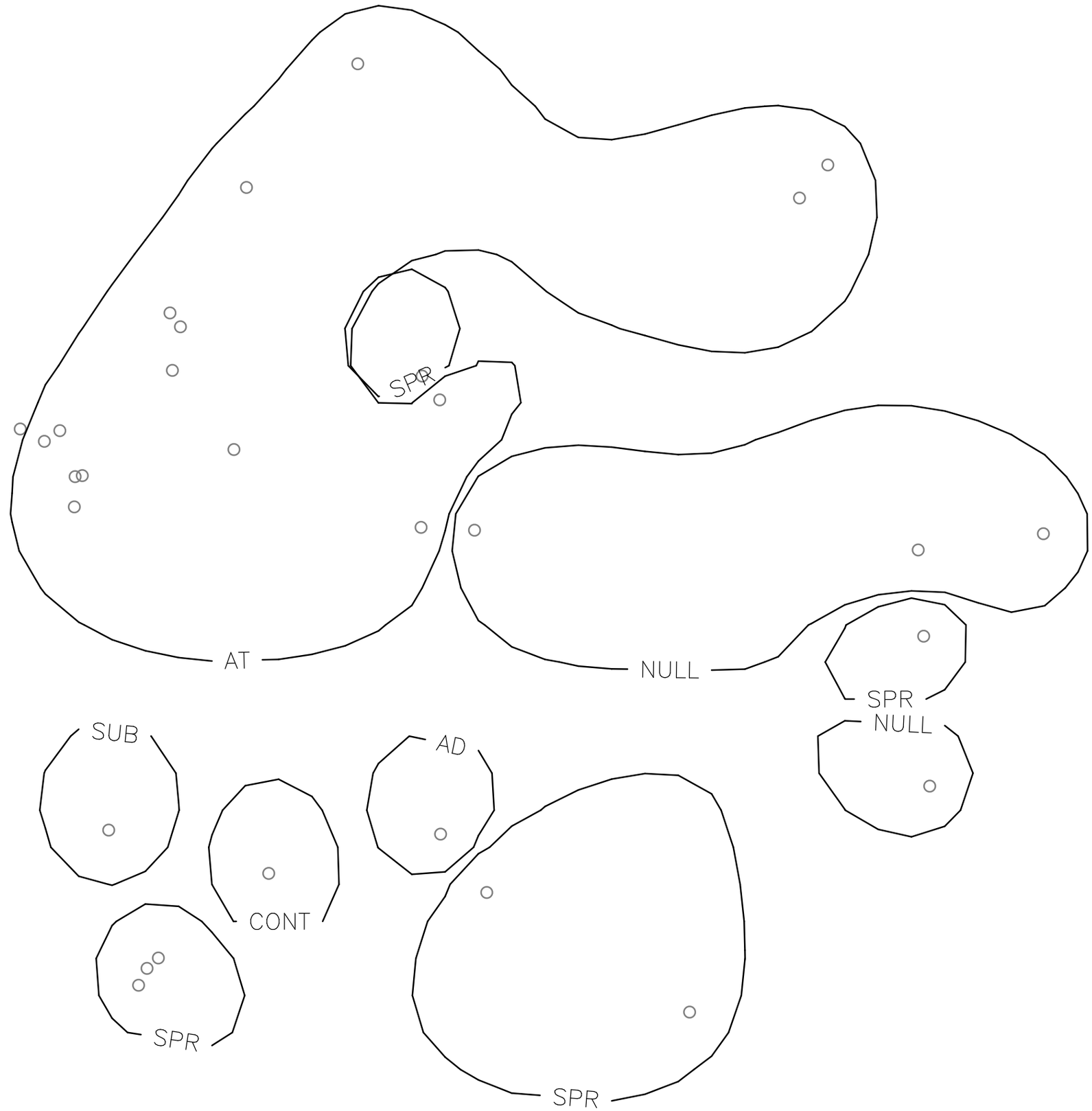
0.2
0.0
−0.2
−0.4
−0.2
0.0
0.2
0.4
0.6

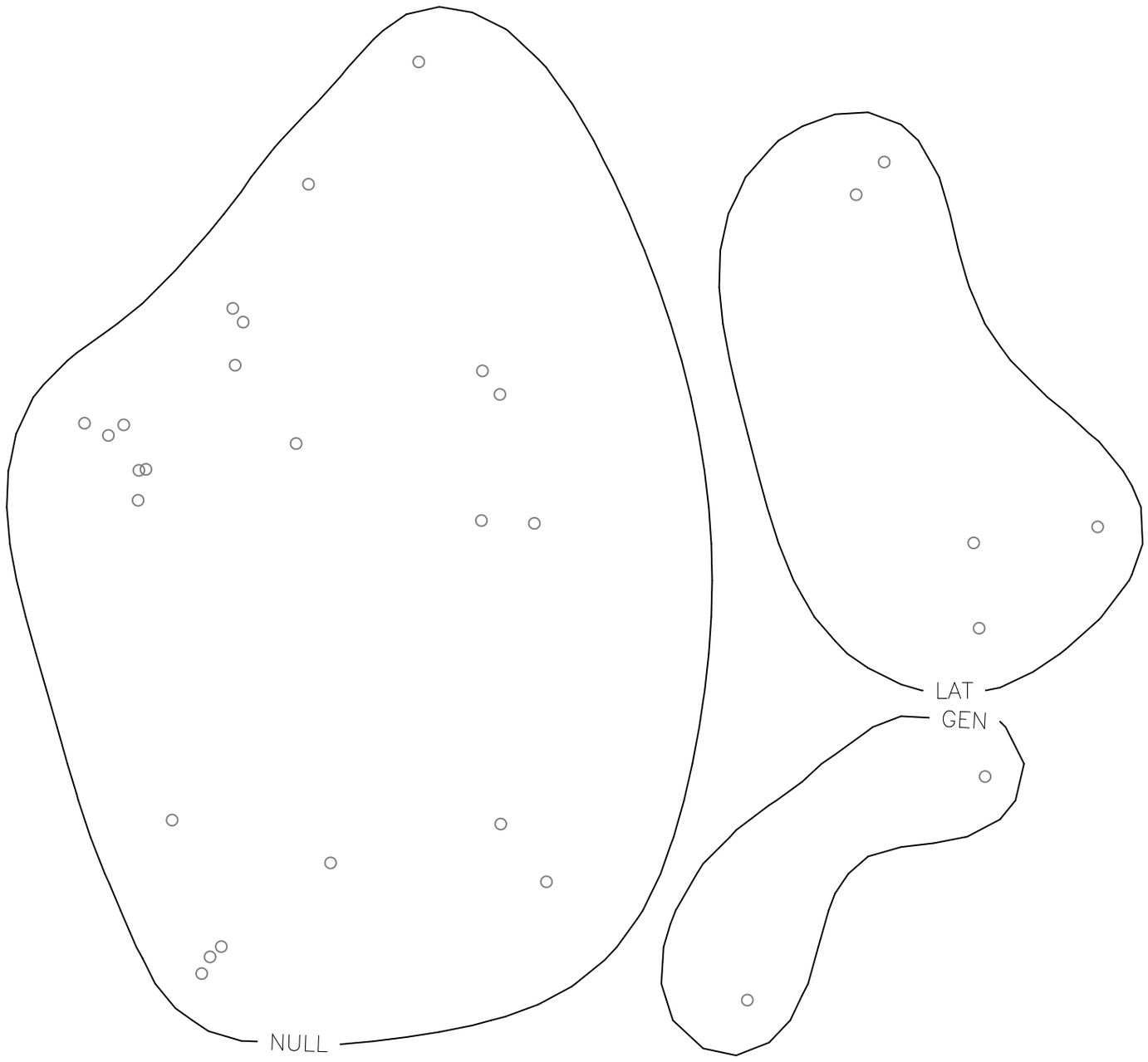


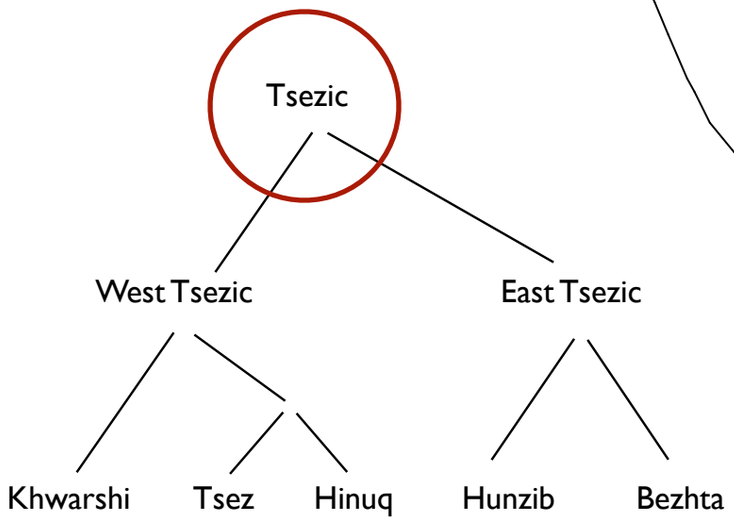




| Function | Hin |
|---|---|
| | Loc |
| ole | AT |
| ge | AT |
| possession | AT |
| sk | AT |
| eg | AT |
| eve | SPR |
| sal | – |
| ative | AT |
| ange | SUB |
| lain | AT |
| ar | AT |
| nd | NULL |
| nanently) | NULL |
| porarily) | AT |
| possession | NULL |
| en | AT |
| ok | SPR |
| rry | AD |
| al location | SPR |
| me | SPR |
| l force | AT |
| ler | AT |
| erior | NULL |
| ntial | AT |
| e/goal | SPR |
| ay | AT |
| out | AT |
| ow | NULL |
| aneous | SPR |
| lk | AT |
| ch | AT |
| ell | AT |
| ative | SPR |
| point | SPR |
| span | CONT |

# Proto-Tsezic

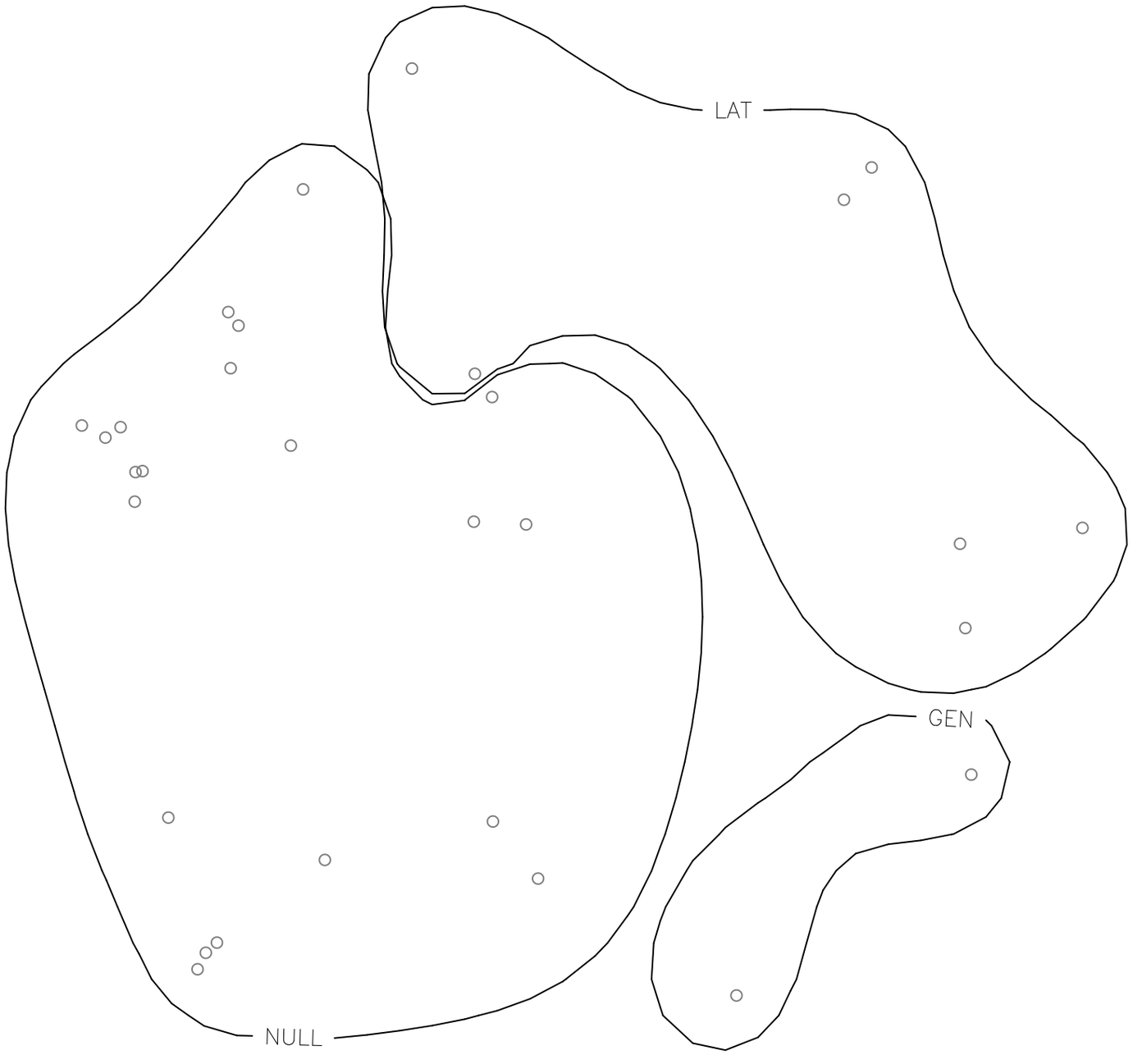
"directional"

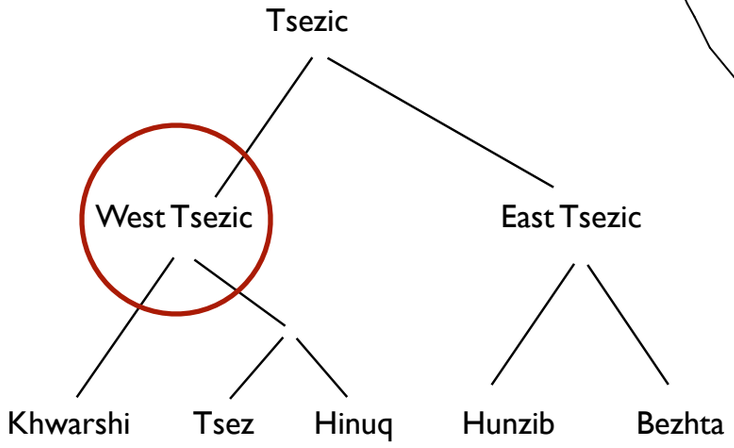


# Proto-West-Tsezic

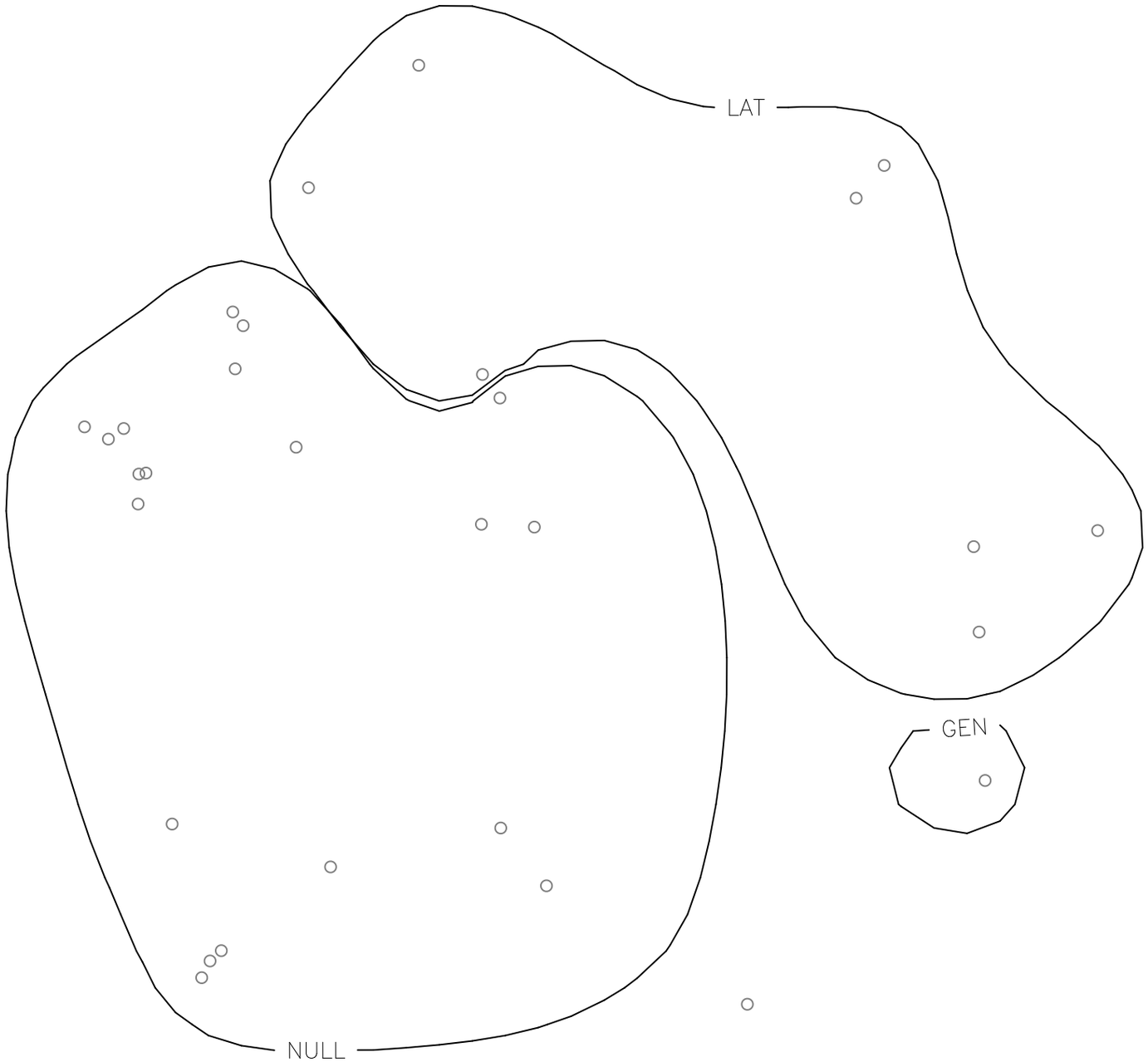
"directional"

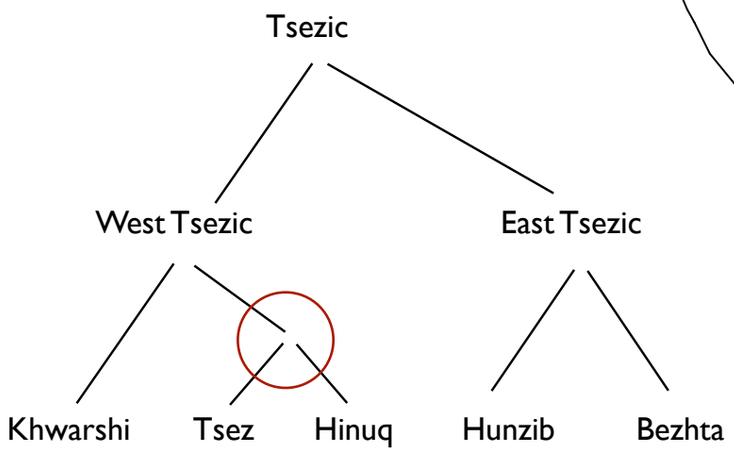


# Proto-Hinuq-Tsez

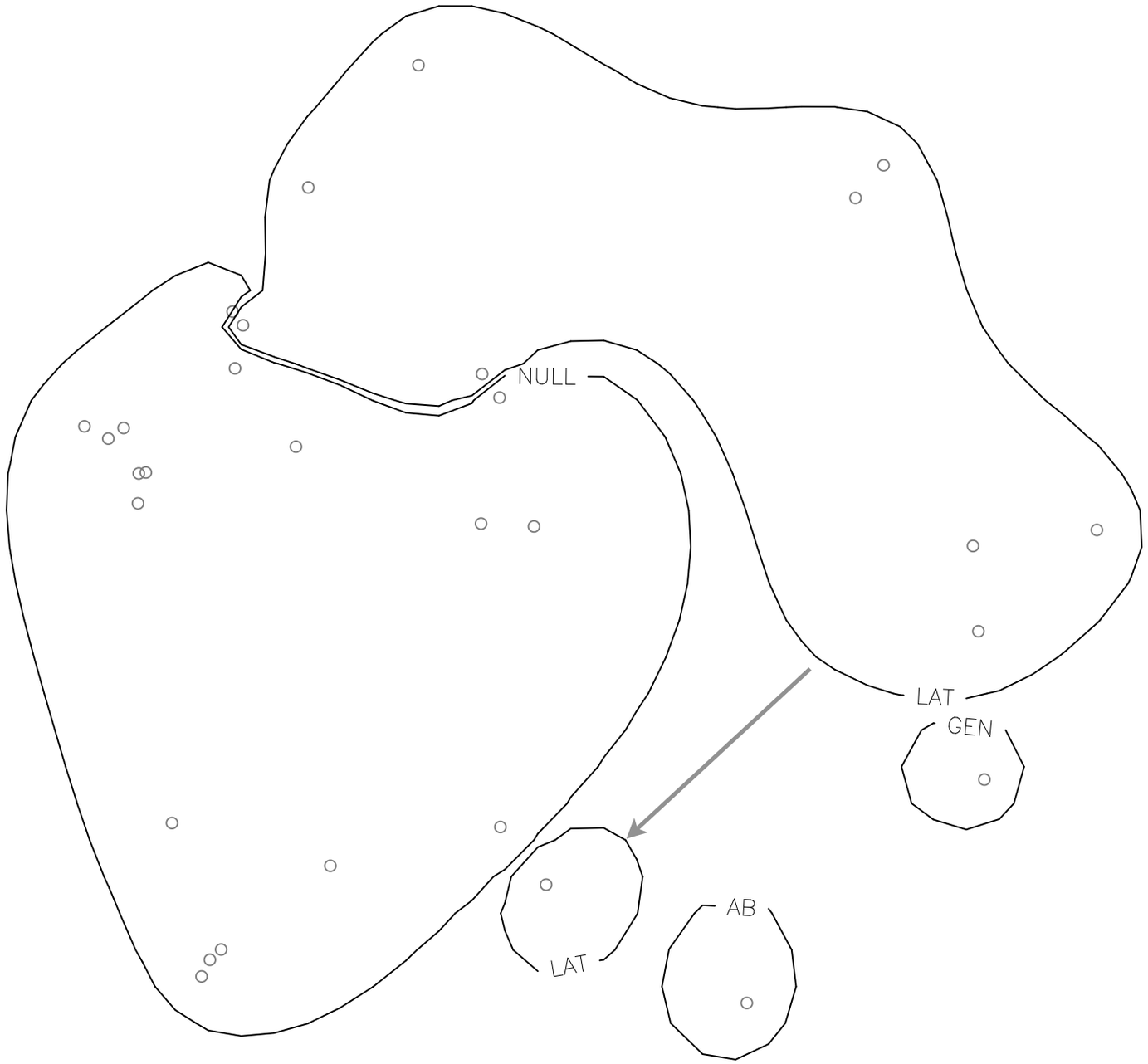
"directional"

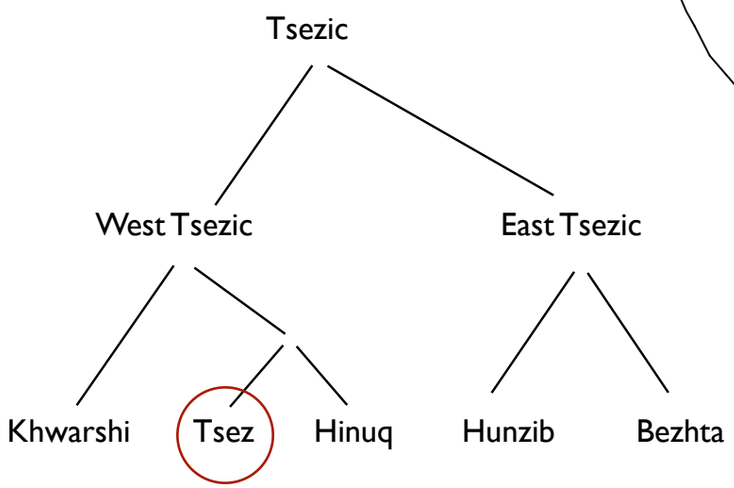


# Tsez

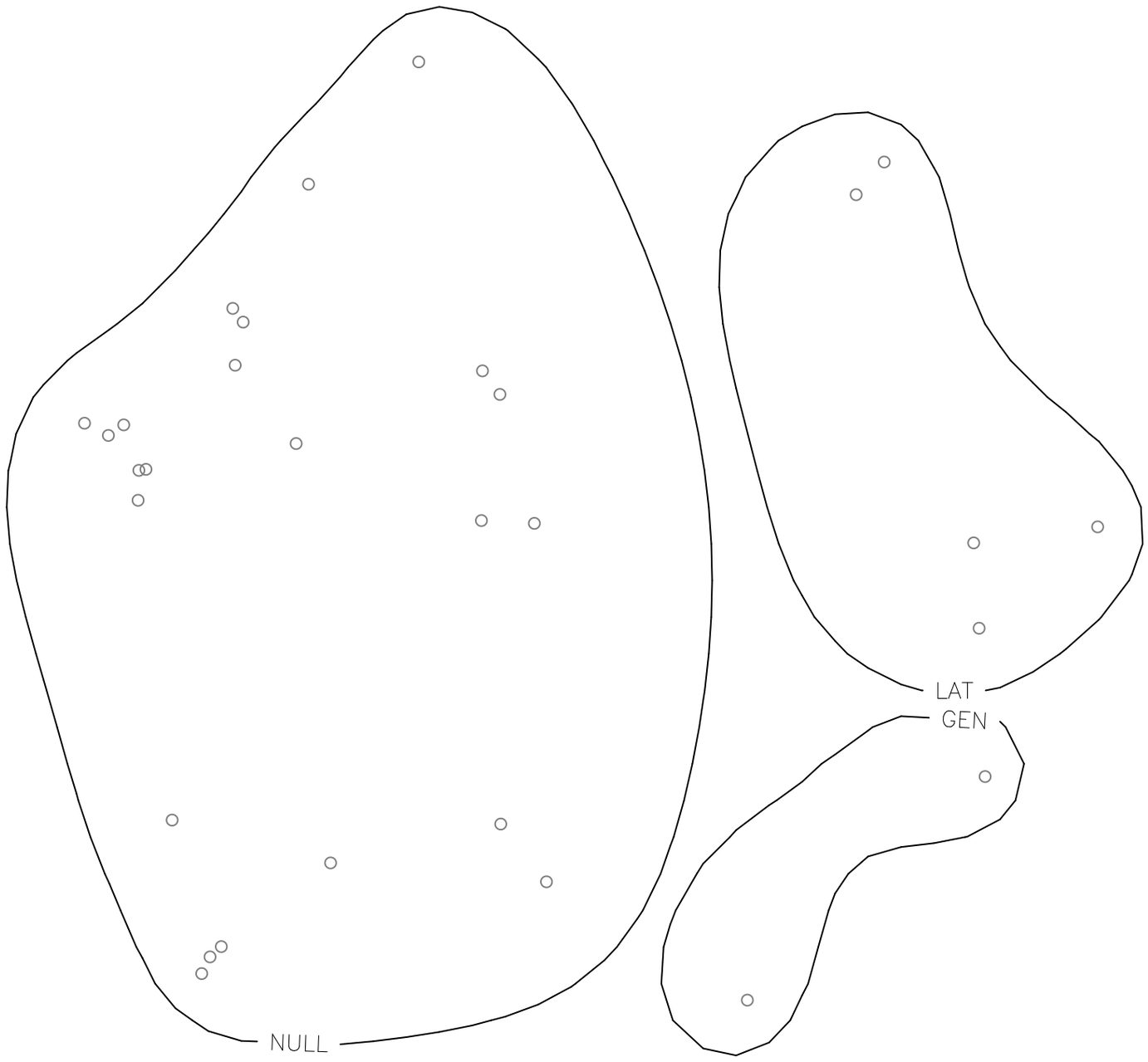
"directional"

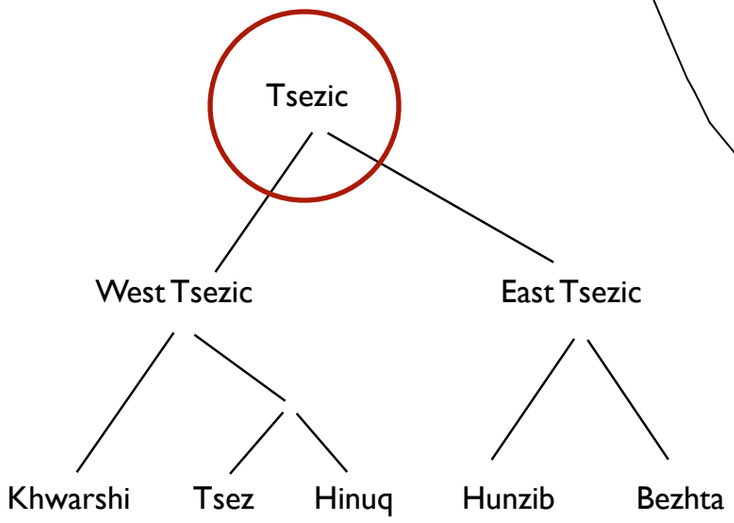


# Proto-Tsezic

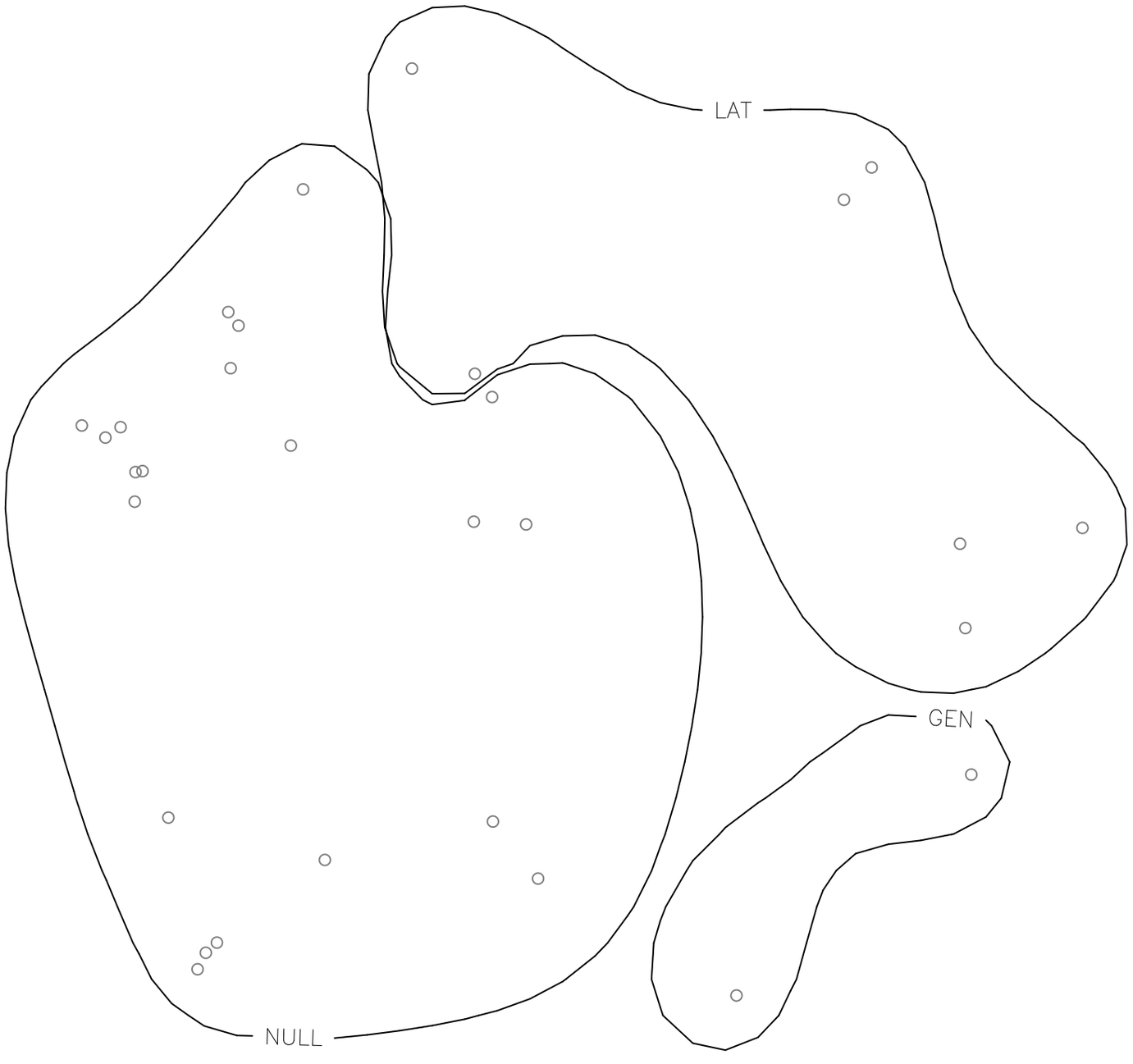
"directional"

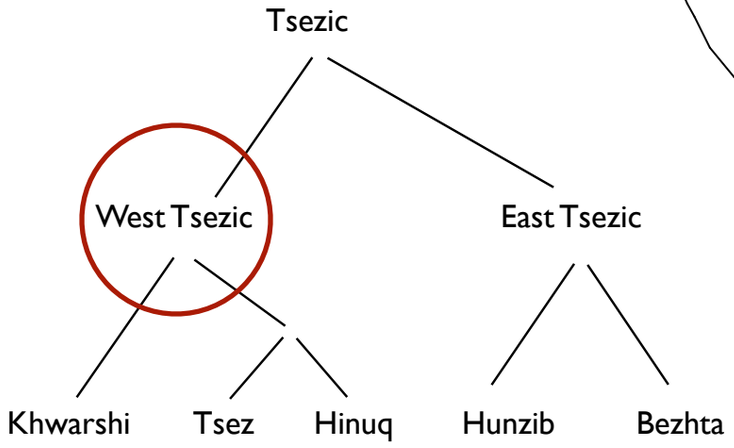


# Proto-West-Tsezic

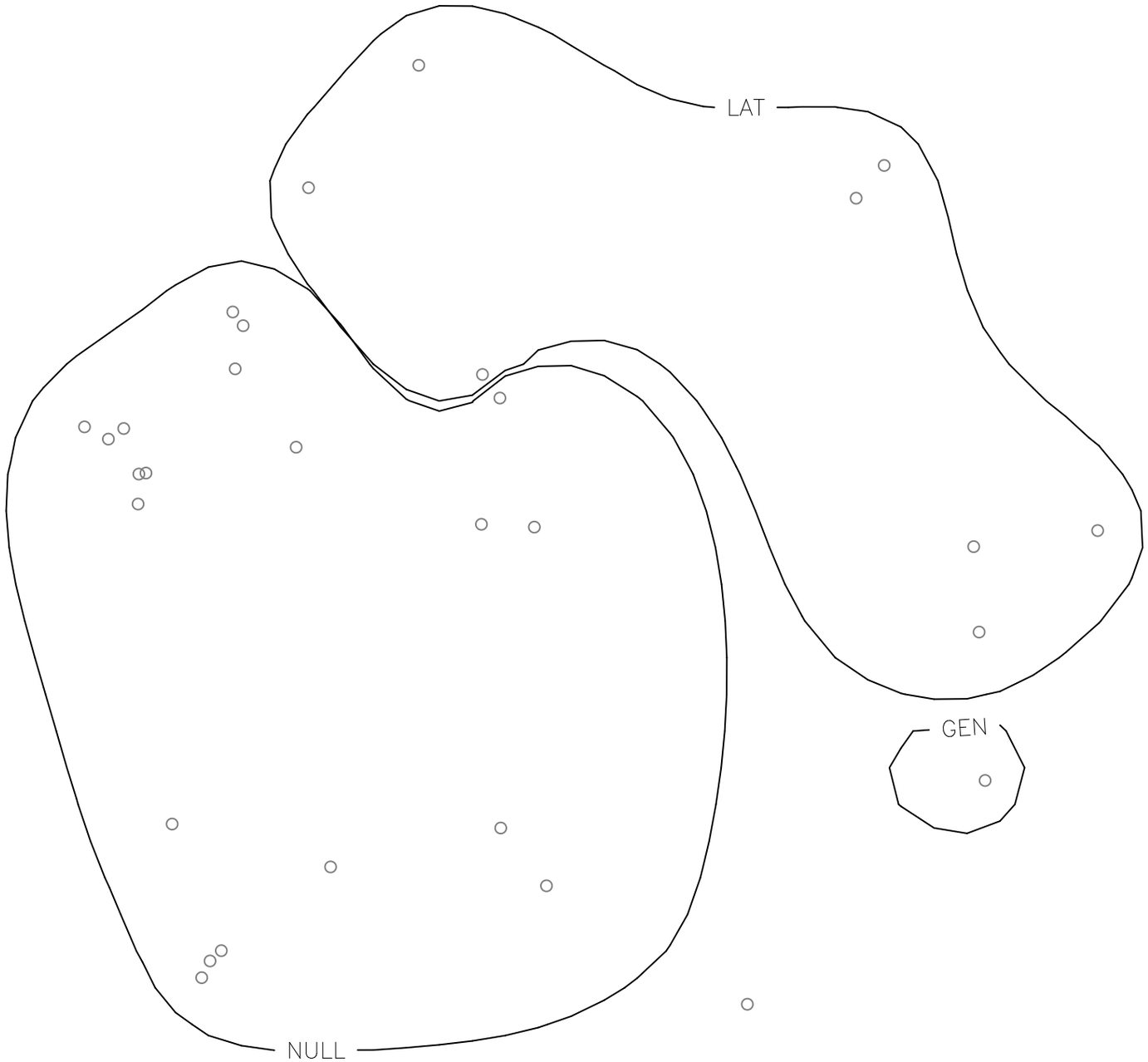
"directional"

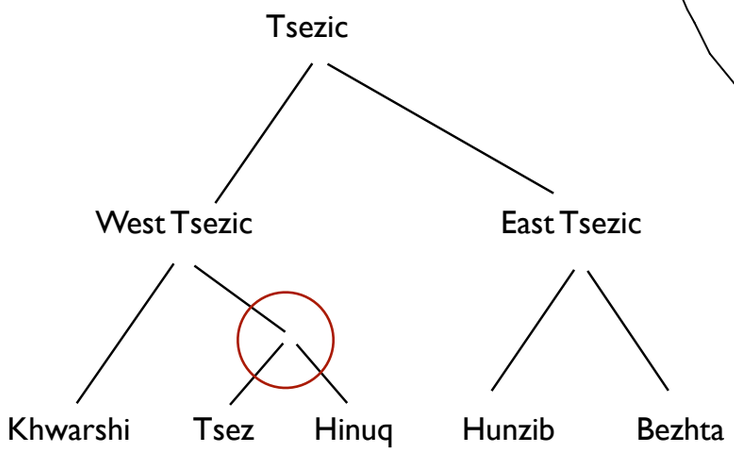


# Proto-Hinuq-Tsez

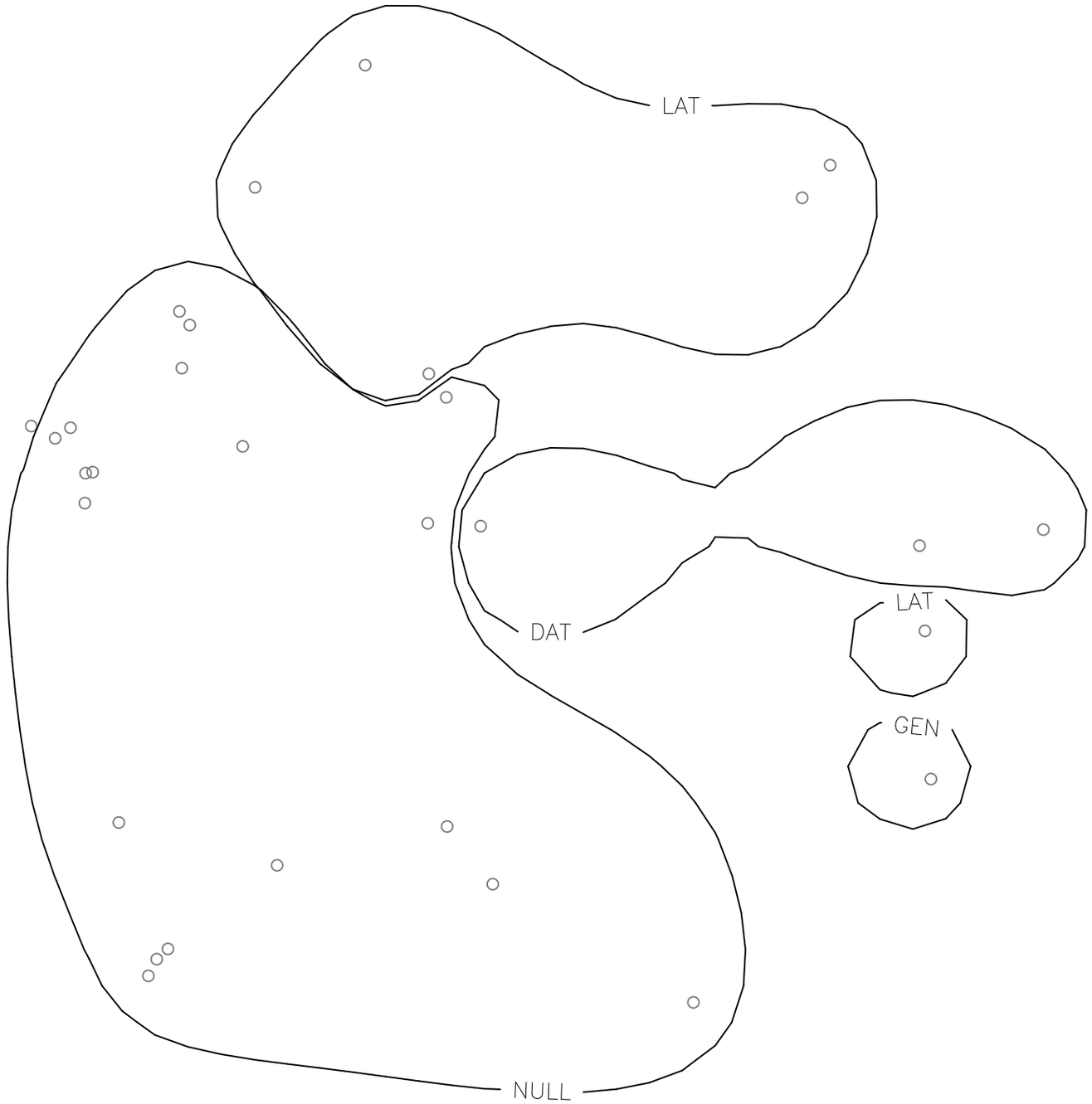
"directional"

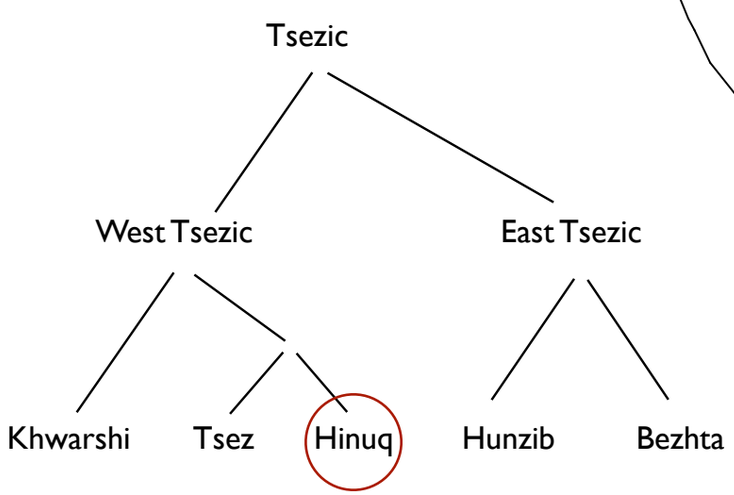


# Hinuq

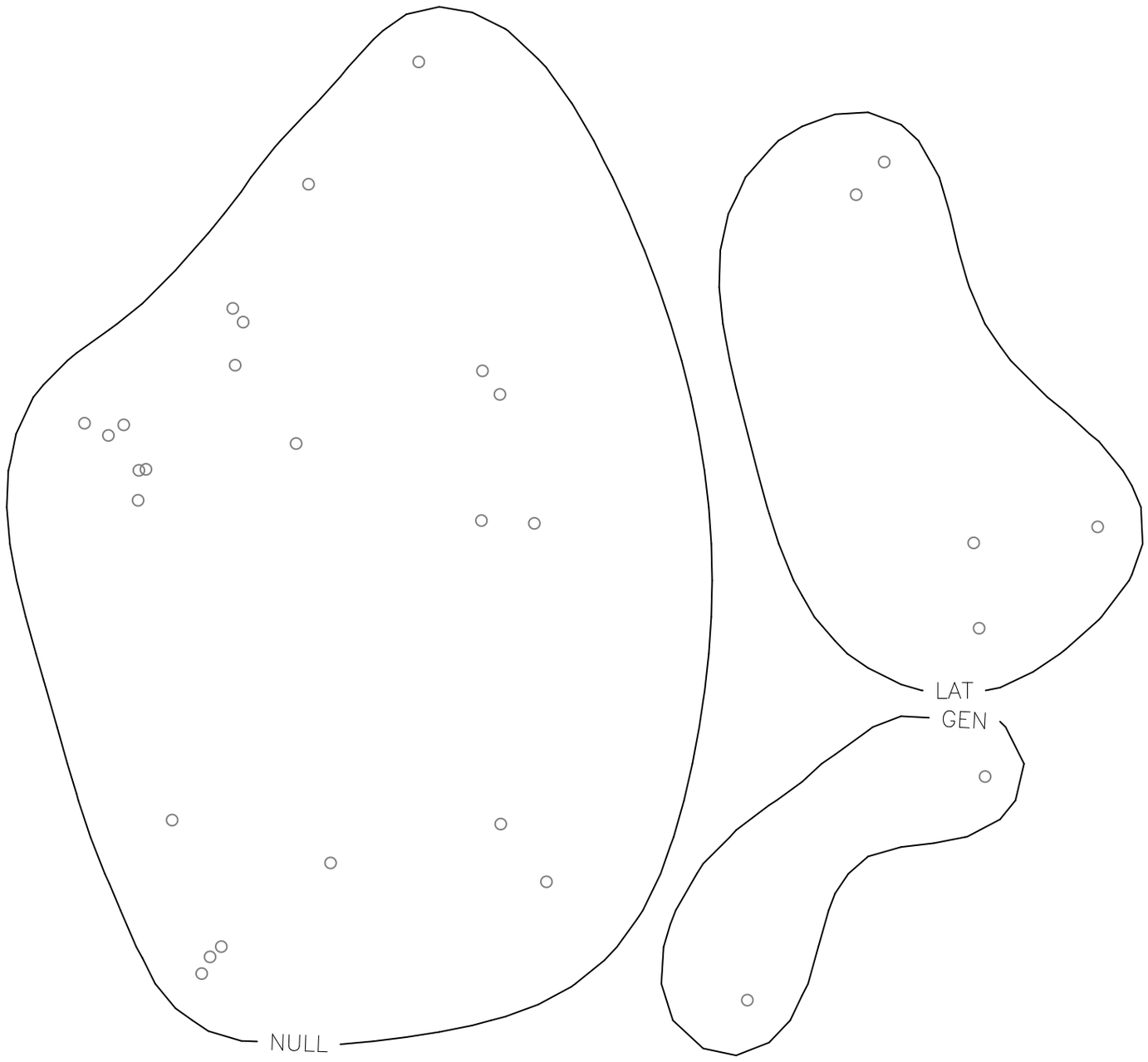
"directional"

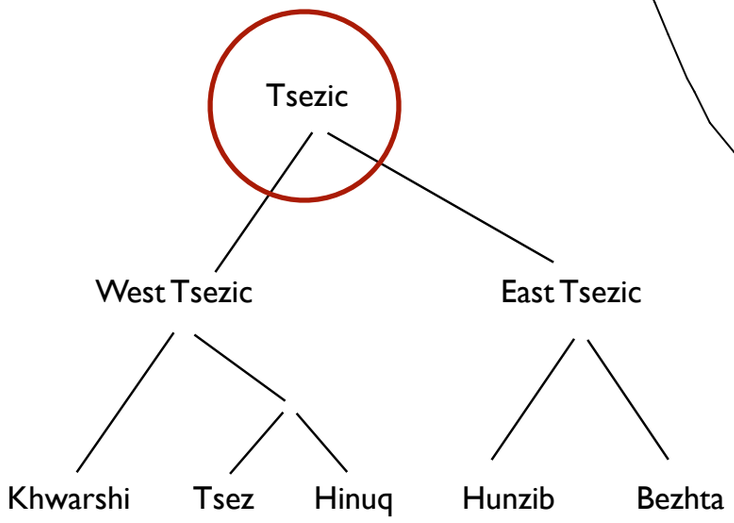


# Proto-Tsezic

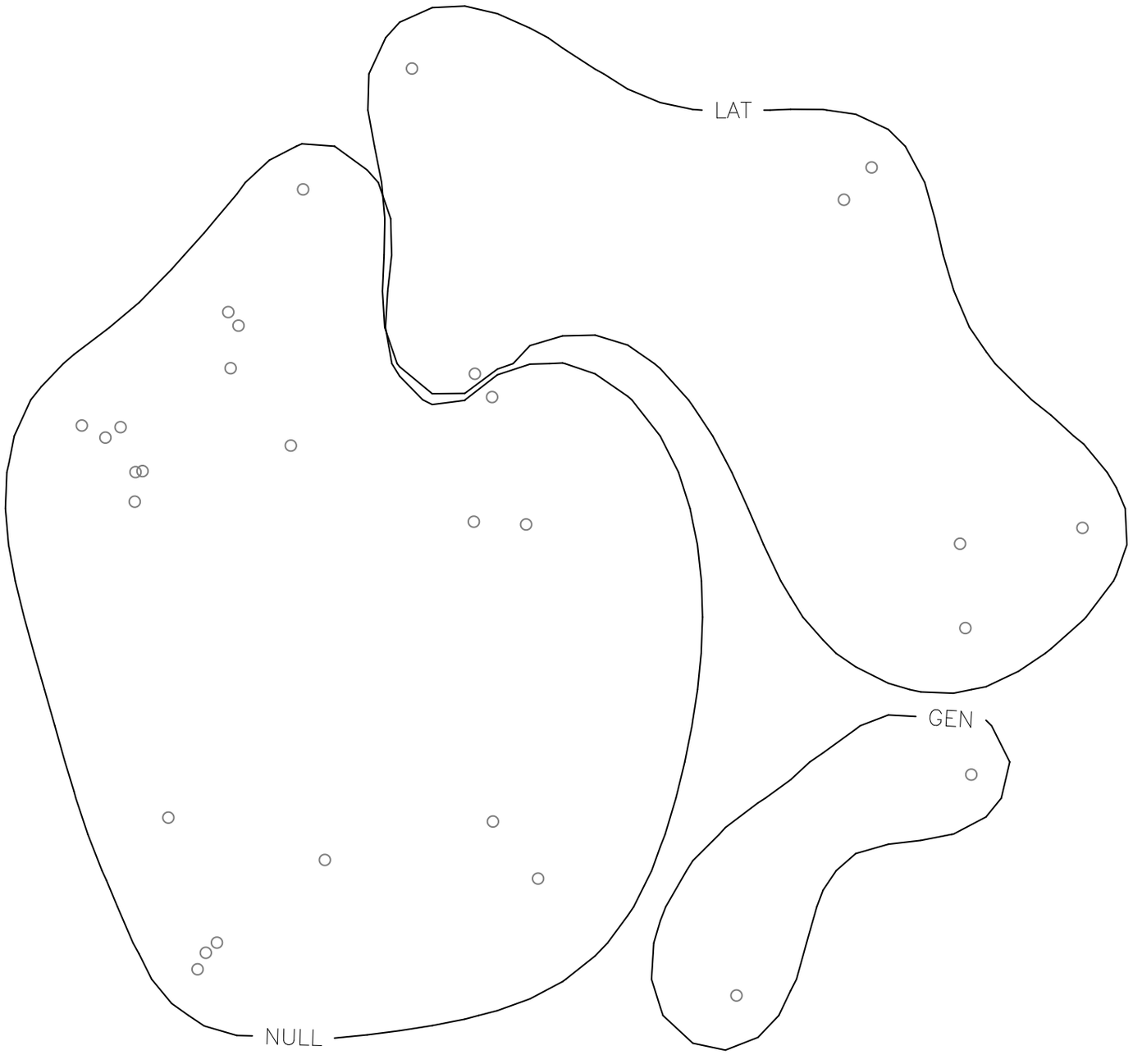
"directional"

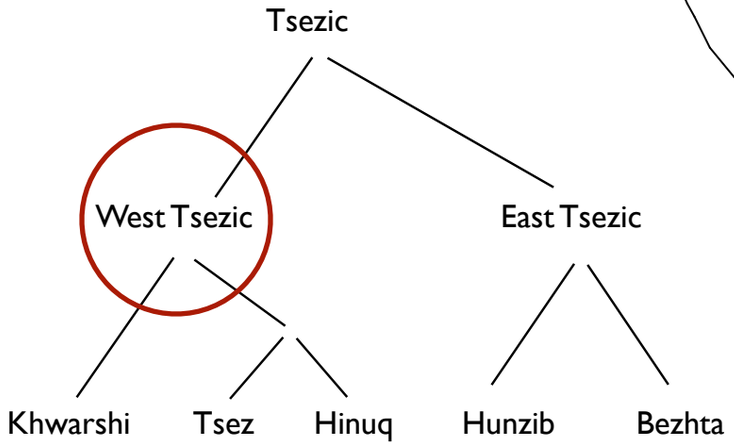


# Proto-West-Tsezic

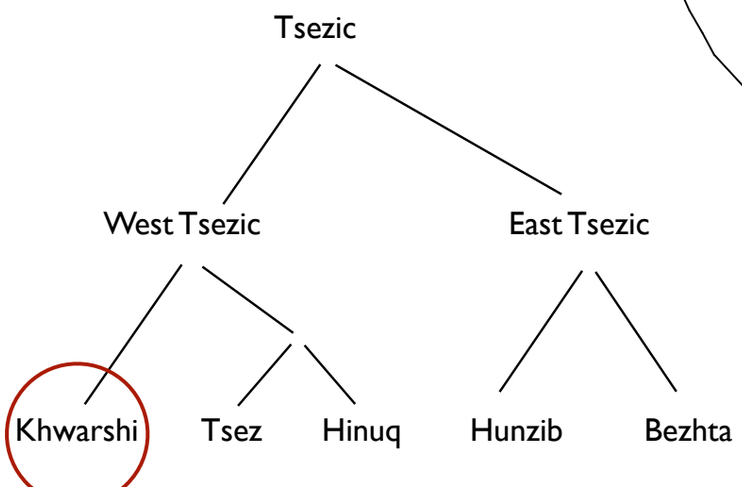
"directional"



# Khwarshi

# “directional”

# Future

- There are only very few linguists that can do the math
- There are only very few mathematicians that know about the dirty details of linguistic structure
- Cooperation between linguists and mathematicians is crucial