Romano P, Gallo V, Ramos R, Antonioli L (2014) Data from: *Atolchelys lepida*, a new side-necked turtle from the Early Cretaceous of Brazil and the age of crown Pleurodira. Dryad Digital Repository. doi:10.5061/dryad.f2h6r

Biology Letters - Electronic Supplementary Material

Atolchelys lepida, a new side-necked turtle from the Early Cretaceous of Brazil and the age of crown Pleurodira

Pedro S. R. Romano, Valéria Gallo, Renato R. C. Ramos, Luzia Antonioli

INTRODUCTION: Location and geology

Atolchelys lepida gen. et sp. nov. holotype UERJ.MC 2 were collected during field work on CIMPOR quarry (former “Atol quarry”) located 6.7 km WNW from the city of São Miguel dos Campos, Alagoas State, Northeastern Brazil by V. Gallo, R.C.C. Ramos, and L. Antonioli at January, 2009. The reference coordinate is 09°45’38” S / 36°09’22” W (Figure S1).

CIMPOR quarry are included in the Morro do Chaves Formation. This lithostratigraphic unit, associated to the rift stage of Sergipe-Alagoas Basin, is characterized by an intercalation of bioclastic calcarenites, calcirudites (coquinas) and shale beds, deposited in a lacustrine paleoenvironment, under seasonal conditions [1]. The studied fossil was found in a carbonate concretion collected at the upper part of the quarry in a thick pelitic interval, related to distal portions of a paleolake, under anoxic conditions.

The Morro do Chaves Formation has been dated as Upper Barremian-Lower Aptian [2]. More recently, Antonioli *et al.* [3], based on the associated occurrences of *Aequitriradites spinulosus*, *Transitoripollis crisopolensis*, and *Dicheiropollis etruscus*, recognized the palynozone *Dicheiropollis etruscus* in the studied stratigraphic section, which suggests a Late Barremian age (Lower Jiquiá local stage).

UERJ.MC 2 was collected in the upper part of the Morro do Chaves Formation, characterized by a pelitic succession with a few sandstone layers (Figure S2). The CIMPOR quarry is shown in Figure S3.

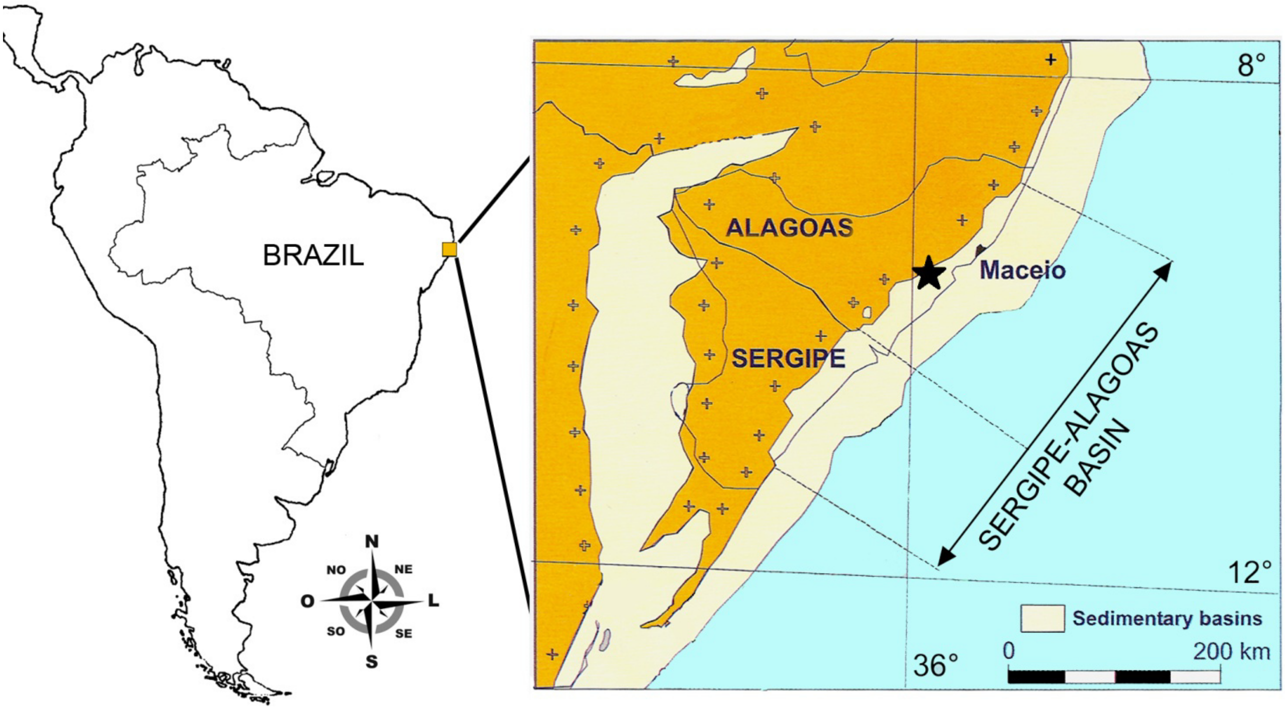

Figure S1. Map showing the position of CIMPOR quarry, type-locality of *Atolchelys lepida* gen. et sp. nov. (black star). Figure by L. Antonioli.

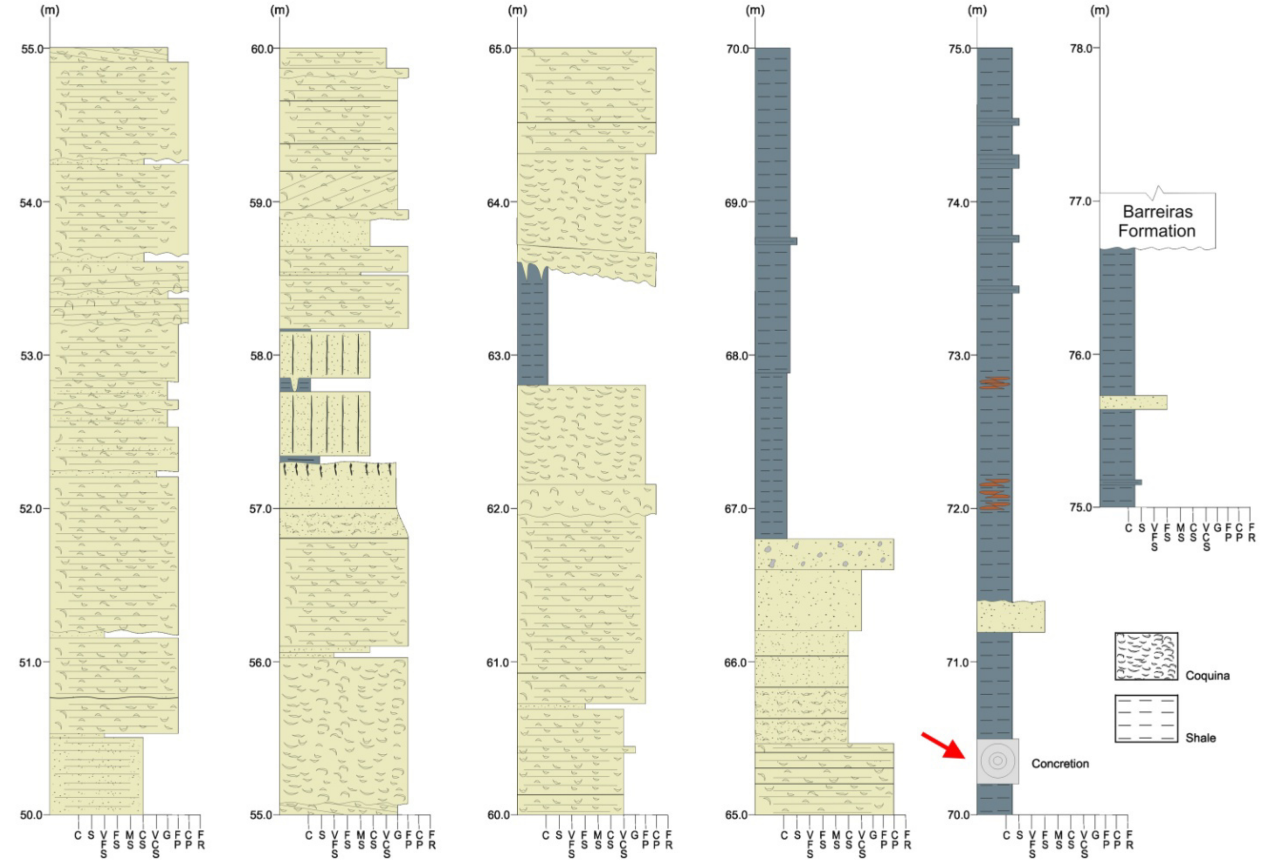

Figure S2. Final stratigraphic sequence (50 to 78m) of CIMPOR quarry, type-locality of *Atolchelys lepida* gen. et sp. nov. The red arrow indicates the position of UERJ.MC 2. Figure by R.C.C. Ramos.

Romano P, Gallo V, Ramos R, Antonioli L (2014) Data from: *Atolchelys lepida*, a new side-necked turtle from the Early Cretaceous of Brazil and the age of crown Pleurodira. Dryad Digital Repository. doi:10.5061/dryad.f2h6r

Figure S3. Panoramic photograph of CIMPOR quarry. The red arrow indicates the position of UERJ.MC 2 in the site; the thin black line indicates the final stratigraphic sequence shown in Figure S2; North (N) South (S) orientation is given. Scale bar of 10 meters. Photo by: R.R.C. Ramos.

INTRODUCTION: Pleurodirans phylogeny and classification

Joyce *et al.* [4] proposed a rank-based taxon names following PhyloCode nomenclature (the crown group convention). However, Gaffney *et al.* (several references, but see [5,6]) keep using monophyletic groups' names following the rules of the ICZN ignoring [4]. As consequence, there is some confusion on side-necked turtle's nomenclature, given the current use of two different nomenclature systems. It is likely that most people will follow the crown group convention from now on. We are following "crown group convention", i.e.: PhyloCode nomenclature [4].

The turtles taxonomy discussion involves the definition of Pleurodira (i.e.: side-necked turtles) and, consequently, the age of it. Such debate regards, among other things, on the phylogenetic position of the European Upper Triassic *Proterochersis* [5,6,7,8,9,10,11].

The traditional ICZN nomenclature for the side-necked turtles [5,6,7,8] includes Platychelyidae and *Proterochersis* as side-necked turtles whereas the PhyloCode nomenclature of "Pleurodira" includes only the first [9,10,11,12] because *Proterochersis* is considered a stem Testudines. So, the apomorphic and nodal definitions of side-necked turtles lies on the debate about the phylogeny of basal turtles [9,10,11,12,13] and is not the objective of the present contribution to address this issue.

The ICZN Casichelydia Gaffney, 1975 equals to PhyloCode Testudines Linnaeus, 1758 (*sensu* [4]). The ICZN "Megapleurodira" clade (*sensu* [14]; i.e.: all pleurodirans, except *Proterochersis*) equals to PhyloCode "Pan-Pleurodira" (*sensu* [4]). The ICZN "Eupleurodira" clade (i.e.: all Megapleurodira except Platychelyidae) equals the PhyloCode "crown Pleurodira" (*sensu* [4]).

Sereno and ElShafie [15] proposed the most comprehensive and updated Phylogenetic definitions for crown groups of Pleurodira. However, the resulted phylogeny (see results) implies on the exclusion of Podocnemidoidea Cope, 1868 as defined in [15] because it would equals to Pelomedusoides Cope, 1868 (node 59 of Figure S4). We preferred the use of Pelomedusoides since it is a more common term in the literature.

MATERIAL AND METHODS

The phylogenetic analysis performed consisted on the inclusion of *Atolchelys lepida* gen. et sp. nov. as a 49th terminal in a data set of 175 parsimony informative characters based on most recent matrix published [5] with subsequent additions and modifications proposed [8,15,16]. *Araripemys* was scored as proposed by [15]. The tree was rooted using [5] outgroup "Synapsida/Diapsida" because the question about the placement of turtles among Amniota would not alter relationships within turtles as analyzed here. We performed all analysis using parsimony search algorithms in TNT version 1.1 [17].

The cladistic analyses were based on a maximum parsimony simultaneous analysis with *a posteriori* polarization of characters using the outgroup [18]. The complete matrix of 175x49 were analyzed via traditional heuristic search, with start trees based on a Wagner search followed by a tree bisection-reconnection (TBR) swapping algorithm with 100 replicates, holding 200 trees in each replicate, and zero random seeds. All characters were left unweighted and the multistate characters were treated as nonadditive (i.e.: Fitch optimization). We reached 24 most parsimonious trees of 437 steps (strict consensus tree in Figure S4).

Besides search strategy described above, we had performed other heuristic searches with more replicates, holding more trees, and changing the number of random seeds. Of course, we have changed the default memory parameter of TNT in order to maximize the number of trees stored in the memory. However, some of the search strategy maximizing the number of permutations exhausted memory limit and did not changed the results (Table S1).

To evaluate, at least partially, if our assumption about connectivity of multistate characters may influence the phylogenetic position of *Atolchelys lepida* gen. et sp. nov. we performed the original search considering all multistate characters as additive. We reached 120 most parsimonious trees of 511 steps. Although the relationships inside Bothremydidae is affected, the phylogenetic positing of *Atolchelys lepida* gen. et sp. nov. do not change.

Bremer (keeping in memory all suboptimal trees up to +5 steps) and bootstrap (1000 replications and cutoff below 50%) clade supports were also calculated using the same search mechanism. The results of Bremer and Bootstrap are in Figures S5 and S6, respectively.

To evaluate the presence of multiple islands disturbing the data, we performed New Technologies search algorithms, changing the number of random seeds to zero (TNT default is 1 random seed, which limits the search performance). By doing it, each new taxon added during tree search is put on several positions until the memory limit is reached. This provide more possible combinations and optimize the performance. First, we ran Ratchet + Tree fusing TNT defaults, resulting in six trees of 437 steps. After, we gradually increased the perturbation to up and down weighting probabilities to +/-6 and +/-10, reaching similar results (i.e.: equal strict consensus tree). Drift strategy (instead of Ratchet) + Tree fusing, using default parameters, also achieved same results of Ratchet + Tree fusing (Table S2). Such results were expected, since it is a relatively small matrix.

Table S1. Comparison of different traditional search mechanism performed in TNT.

Search	Original	2nd	3th	4th	5th	6th
Algorithm	TBR	TBR	TBR	TBR	TBR	TBR
Number of replicas	100	100	1000	1000	10000	10000
Number of random seeds	0	10	0	10	0	10
Number of trees hold each time	200	200	200	500	500	500
Number of steps	437	437	437	437	437	437
Most parsimonious trees retained	24	24	24	24	24	24
Number of times hitting best score	90 of 100	96 of 100	928 of 1000	927 of 1000	9216 of 10000	9234 of 10000
Number of rearranges exanimated	43.958.187	29.514.145	322.816.711	311.452.946	3.237.103.346	3.255.186.540
Time consumed	0:00:01	0:00:01	0:00:12	0:00:11	0:01:20	0:02:01

Table S2. Comparison of different New Technology search mechanism performed in TNT.

Search	Ratchet #1	Ratchet #2	Ratchet #3	Drift
Up and down weighting probabilities	+/- 4	+/- 6	+/- 10	---
Number of random seeds	0	0	0	0
Best score (number of steps)	437	437	437	437
Most parsimonious trees retained	6	5	6	7
Number of rearranges exanimate	4.622.122	4.588.509	4.698.450	4.751.518

RESULTS: Resulted trees

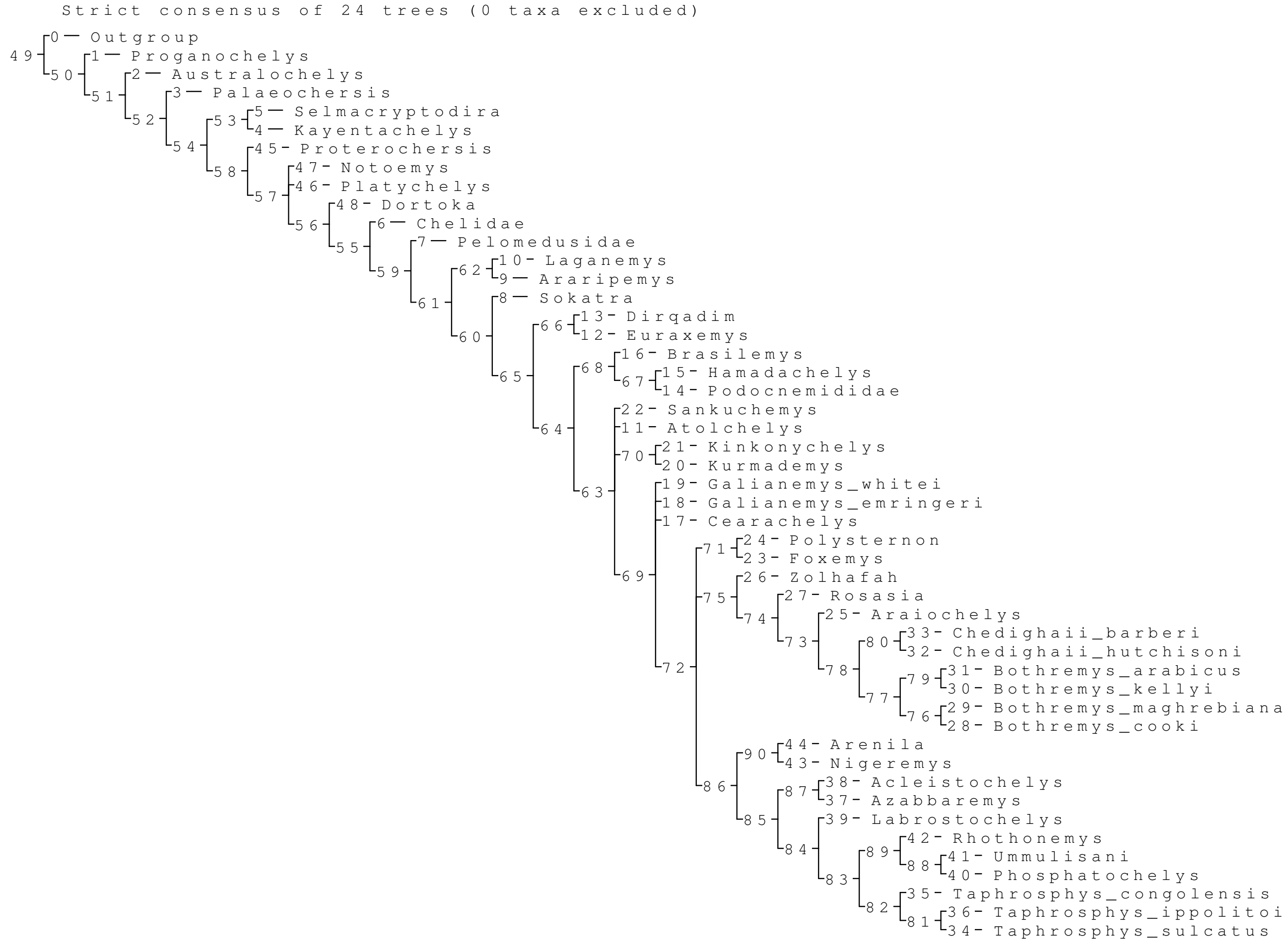

Figure S4. Strict consensus tree of 24 most parsimony trees of 437 steps (see Tables S1 and S2). Numbers in the nodes represent nodes to apomorphies mapping described below. Figure by P. S. R. Romano.

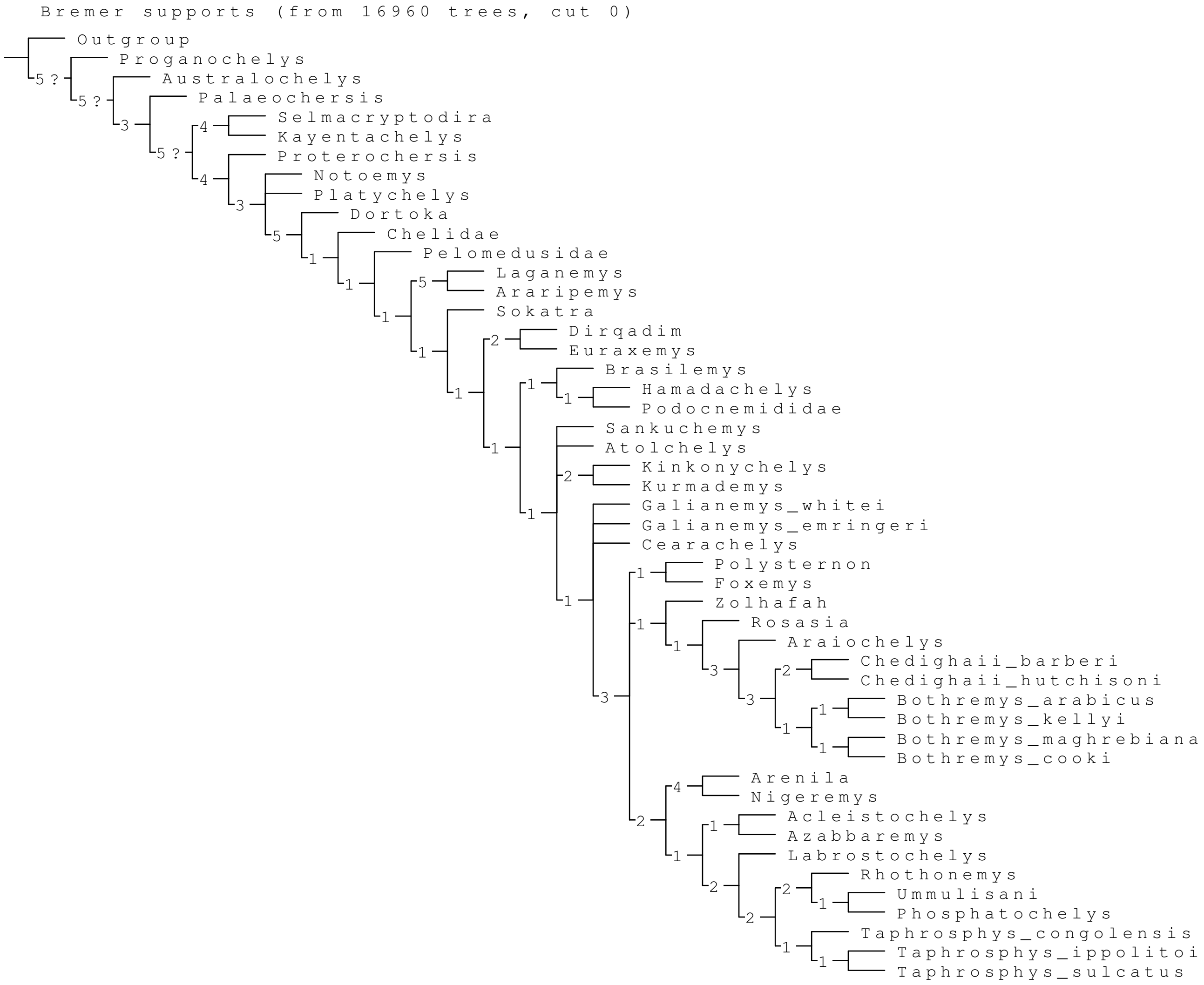

Figure S5. Bremer consensus tree of TBR original search. Numbers in the nodes represent Bremer support value. The "?" indicate suboptimal length not explored (i.e.: equal or higher than +6 steps). Figure by P. S. R. Romano.

Figure S6. Bootstrap consensus tree of TBR original search. Numbers in the nodes represent Bootstrap % support (1000 replications). Nodes collapsed if Bootstrap below 50%. Figure by P. S. R. Romano.

RESULTS: List of synapomorphies

All synapomorphies common to24 most parsimonious trees. Node numbers refer to nodes in consensus, see Figure S4.

Outgroup
All trees:
No autapomorphies

Proganochelys
All trees:
No autapomorphies

Australochelys
All trees:
Char. 41: 0 --> 1

Palaeochersis
All trees:
No autapomorphies

Kayentachelys
All trees:
No autapomorphies

Selmacryptodira
All trees:
Char. 73: 0 --> 4
Char. 74: 0 --> 1

Chelidae
All trees:
Char. 37: 0 --> 2
Char. 172: 0 --> 1
Some trees:
Char. 149: 1 --> 0

Pelomedusidae
All trees:
Char. 44: 1 --> 2
Char. 46: 0 --> 2
Char. 75: 0 --> 1
Char. 83: 0 --> 1
Char. 88: 0 --> 1
Char. 140: 0 --> 123

Sokatra
All trees:
Char. 103: 0 --> 2
Some trees:
Char. 84: 0 --> 4

Araripemys
All trees:
Char. 10: 0 --> 1
Char. 120: 0 --> 1
Char. 147: 1 --> 0
Char. 157: 2 --> 3
Some trees:
Char. 149: 1 --> 0

Laganemys
All trees:
Char. 12: 0 --> 1
Char. 13: 1 --> 2
Char. 28: 0 --> 1
Char. 83: 0 --> 1
Char. 119: 1 --> 0
Char. 140: 0 --> 1

Atolchelys
All trees:
Char. 18: 1 --> 0
Char. 29: 0 --> 1
Char. 34: 0 --> 1
Char. 105: 2 --> 4
Some trees:
Char. 10: 0 --> 1
Char. 30: 1 --> 0
Char. 67: 0 --> 1
Char. 68: 0 --> 1
Char. 84: 1 --> 2
Char. 163: 0 --> 1

Euraxemys
All trees:
No autapomorphies:

Dirqadim
All trees:
Char. 14: 1 --> 0
Char. 29: 0 --> 1
Char. 76: 0 --> 1

Podocnemididae
All trees:
Char. 118: 0 --> 1
Char. 121: 0 --> 1

Hamadachelys
All trees:
No autapomorphies:

Brasilemys
All trees:
Char. 55: 2 --> 1
Char. 126: 2 --> 1
Some trees:
Char. 84: 0 --> 3

Cearachelys
All trees:
Char. 26: 1 --> 0
Char. 51: 1 --> 02
Some trees:
Char. 19: 0 --> 1
Char. 52: 1 --> 0
Char. 143: 0 --> 1
Char. 164: 1 --> 0
Char. 174: 1 --> 4

Galianemys emringeri
Some trees:
Char. 67: 0 --> 1
Char. 94: 0 --> 1

Galianemys whitei
All trees:
No autapomorphies

Kurmademys
All trees:
No autapomorphies

Kinkonychelys
All trees:
Char. 94: 1 --> 2
Some trees:
Char. 59: 1 --> 0
Char. 83: 0 --> 1

Sankuchemys
All trees:
No autapomorphies

Foxemys
All trees:
Char. 41: 0 --> 1
Some trees:
Char. 94: 0 --> 1

Polysternon
All trees:
Char. 59: 0 --> 1
Char. 174: 1 --> 3
Some trees:
Char. 153: 0 --> 1
Char. 163: 1 --> 0

Araiochelys
All trees:
Char. 4: 1 --> 0
Char. 33: 2 --> 1
Char. 76: 0 --> 1
Char. 144: 2 --> 4
Char. 145: 2 --> 3
Char. 166: 0 --> 1
Some trees:
Char. 117: 1 --> 0

Zolhafah
All trees:
Char. 73: 4 --> 5
Some trees:
Char. 78: 1 --> 0

Rosasia
All trees:
Char. 67: 0 --> 1
Char. 164: 1 --> 0

Bothremys cooki
All trees:
No autapomorphies

Bothremys maghrebiana
All trees:
Char. 76: 0 --> 1

Bothremys kellyi
All trees:
Char. 73: 1 --> 5

Bothremys arabicus
All trees:
No autapomorphies:

Chedighaii hutchisoni
All trees:
Char. 30: 2 --> 1

Chedighaii barberi
All trees:
Char. 33: 2 --> 1

Taphrosphys sulcatus
All trees:
Char. 86: 1 --> 0

Taphrosphys congolensis
All trees:
No autapomorphies

Taphrosphys ippolitoi
All trees:
No autapomorphies

Azabbaremys
All trees:
Char. 29: 0 --> 1
Char. 30: 1 --> 0
Char. 50: 3 --> 2
Some trees:
Char. 23: 1 --> 0

Acleistochelys
All trees:
Char. 22: 0 --> 1
Char. 34: 0 --> 1

Char. 35: 0 --> 1
Char. 67: 0 --> 2
Char. 73: 1 --> 5

Labrostochelys
All trees:
Char. 5: 0 --> 1

Char. 6: 0 --> 1
Char. 29: 0 --> 1
Char. 30: 1 --> 2
Char. 39: 0 --> 2
Char. 48: 1 --> 0
Char. 50: 3 --> 1
Char. 74: 1 --> 0

Phosphatochelys
All trees:
Char. 15: 0 --> 1

Ummulisani
All trees:
Char. 5: 0 --> 1
Char. 50: 3 --> 2
Char. 79: 1 --> 0

Rhothonemys
All trees:
Char. 29: 0 --> 1

Nigeremys
All trees:
No autapomorphies

Arenila
All trees:
No autapomorphies

Proterochersis
All trees:
Char. 139: 2 --> 1
Char. 150: 2 --> 1
Char. 171: 0 --> 1

Platychelys
All trees:
Char. 150: 2 --> 1
Char. 171: 0 --> 1

Notoemys
All trees:
No autapomorphies

Dortoka
All trees:
Char. 142: 0 --> 1
Char. 147: 1 --> 2
Char. 169: 0 --> 2

Node 50
All trees:
No synapomorphies

Node 51 :
All trees:
Char. 45: 0 --> 1
Char. 60: 0 --> 1
Char. 62: 0 --> 1

Char. 64: 0 --> 1
Char. 65: 0 --> 1
Char. 66: 0 --> 1
Char. 79: 0 --> 1
Char. 96: 0 --> 1
Char. 107: 0 --> 1
Char. 108: 0 --> 1
Char. 110: 0 --> 1

Node 52
All trees:
Char. 61: 0 --> 1
Char. 63: 0 --> 1
Char. 104: 0 --> 1

Node 53
All trees:
Char. 7: 0 --> 1
Char. 28: 0 --> 1
Char. 71: 0 --> 1
Char. 95: 0 --> 1

Node 54
All trees:
Char. 2: 0 --> 1
Char. 31: 0 --> 1
Char. 50: 0 --> 3
Char. 80: 0 --> 1
Char. 82: 0 --> 1
Char. 87: 0 --> 1
Char. 97: 0 --> 1
Char. 110: 1 --> 2
Char. 111: 0 --> 1
Char. 129: 0 --> 1
Char. 130: 0 --> 1
Char. 139: 0 --> 2
Char. 150: 0 --> 2
Char. 158: 0 --> 1

Node 55
All trees:
Char. 128: 1 --> 2
Char. 144: 0 --> 2

Node 56
All trees:
Char. 125: 0 --> 1
Char. 138: 0 --> 1

Node 57
All trees:
Char. 147: 0 --> 1
Char. 159: 0 --> 1
Some trees:
Char. 157: 0 --> 1
Char. 161: 0 --> 1
Char. 170: 0 --> 1

Node 58
All trees:
Char. 131: 0 --> 1
Char. 132: 0 --> 1
Char. 133: 0 --> 1
Char. 134: 0 --> 1
Char. 153: 1 --> 0
Char. 167: 0 --> 1
Char. 173: 0 --> 1

Node 59
All trees:
Char. 0: 0 --> 1
Char. 3: 0 --> 1
Char. 13: 0 --> 1
Char. 14: 0 --> 1
Char. 112: 0 --> 1
Char. 127: 2 --> 1
Char. 137: 0 --> 1

Node 60
All trees:
Char. 93: 0 --> 1
Char. 98: 0 --> 1
Some trees:
Char. 35: 0 --> 1

Node 61
All trees:
Char. 124: 0 --> 1

Node 62
All trees:
Char. 29: 0 --> 1
Char. 39: 0 --> 3
Char. 49: 0 --> 1
Char. 76: 0 --> 1
Char. 105: 2 --> 3
Char. 128: 2 --> 0
Char. 138: 1 --> 4
Char. 143: 0 --> 2
Char. 152: 0 --> 1
Char. 153: 0 --> 1
Char. 158: 1 --> 0
Char. 171: 0 --> 2
Char. 174: 1 --> 5

Node 63
Some trees:
Char. 26: 0 --> 1
Char. 30: 0 --> 1
Char. 33: 0 --> 1
Char. 37: 0 --> 1
Char. 51: 02 --> 1
Char. 52: 0 --> 1
Char. 75: 0 --> 1
Char. 78: 0 --> 1
Char. 84: 0 --> 1
Char. 94: 0 --> 1
Char. 101: 0 --> 1
Char. 113: 0 --> 1
Char. 115: 0 --> 1
Char. 117: 0 --> 1

Node 64
All trees:
Char. 58: 0 --> 1
Char. 86: 0 --> 1
Char. 93: 1 --> 2
Char. 103: 0 --> 1
Char. 164: 0 --> 1

Node 65
All trees:
Char. 74: 0 --> 1
Some trees:
Char. 13: 1 --> 0

Node 66
All trees:
Char. 12: 0 --> 1
Char. 55: 2 --> 1
Char. 85: 0 --> 1
Char. 105: 2 --> 1
Some trees:
Char. 84: 0 --> 2

Node 67
All trees:
Char. 12: 0 --> 1
Some trees:
Char. 81: 1 --> 2

Node 68
All trees:
Char. 140: 0 --> 1
Some trees:
Char. 35: 1 --> 0
Char. 68: 0 --> 1

Node 69
All trees:
Char. 28: 0 --> 1
Char. 55: 2 --> 0
Char. 91: 0 --> 1
Some trees:
Char. 13: 1 --> 2
Char. 43: 1 --> 0
Char. 59: 1 --> 0
Char. 100: 0 --> 1
Char. 105: 2 --> 1

Node 70
All trees:
Char. 73: 4 --> 2
Char. 74: 1 --> 0
Some trees:
Char. 54: 0 --> 1
Char. 67: 0 --> 1
Char. 81: 1 --> 2
Char. 99: 0 --> 1

Node 71
All trees:
Char. 67: 0 --> 2
Char. 138: 1 --> 2
Char. 172: 0 --> 1
Some trees:
Char. 52: 1 --> 0
Char. 105: 1 --> 2
Char. 165: 0 --> 1

Node 72
All trees:
Char. 56: 0 --> 1
Char. 92: 0 --> 1
Char. 118: 0 --> 1
Char. 119: 1 --> 0
Char. 121: 0 --> 1
Char. 140: 0 --> 2
Some trees:
Char. 13: 2 --> 0
Char. 23: 0 --> 1
Char. 99: 0 --> 1
Char. 100: 1 --> 0
Char. 120: 0 --> 1

Char. 163: 0 --> 1

Node 73
All trees:
Char. 5: 0 --> 1
Char. 6: 0 --> 1
Char. 29: 0 --> 1
Char. 31: 1 --> 2
Char. 73: 4 --> 1
Node 74
All trees:
Char. 30: 1 --> 2

Node 75
All trees:
Char. 22: 0 --> 1
Char. 34: 0 --> 1

Node 76
All trees:
Char. 40: 0 --> 1

Node 77
All trees:
Char. 39: 0 --> 1
Node 78
All trees:
Char. 10: 0 --> 1
Char. 36: 0 --> 1
Char. 102: 0 --> 1
Char. 103: 1 --> 2
Node 79
All trees:
Char. 30: 2 --> 1

Node 80
All trees:
Char. 22: 1 --> 0
Char. 34: 1 --> 0

Node 81
All trees:
Char. 109: 0 --> 1

Node 82
All trees:
Char. 73: 1 --> 5

Node 83
All trees:
Char. 32: 0 --> 1
Char. 72: 0 --> 1
Char. 103: 2 --> 1
Char. 105: 1 --> 2
Some trees:
Char. 23: 1 --> 0

Node 84
All trees:
Char. 12: 0 --> 2
Char. 24: 0 --> 1
Char. 25: 0 --> 1
Char. 28: 1 --> 0
Char. 53: 0 --> 1

Node 85
All trees:
Char. 27: 1 --> 2
Char. 42: 0 --> 1
Char. 73: 4 --> 1

Node 86
All trees:
Char. 48: 0 --> 1
Char. 103: 1 --> 2
Some trees:
Char. 49: 1 --> 0
Node 87
All trees:
Char. 43: 0 --> 1
Char. 46: 0 --> 1

Node 88
All trees:
Char. 9: 0 --> 1

Node 89
All trees:
Char. 17: 0 --> 1
Char. 36: 0 --> 1
Char. 39: 0 --> 3

Node 90
All trees:
Char. 50: 3 --> 2
Char. 59: 0 --> 2
Char. 67: 0 --> 2
Char. 105: 1 --> 4

DISCUSSION: Biogeography

A previous hypothesis [19, agreeing with 20] suggests that the Pelomedusoides-Chelidae split is consistent with a vicariance event that occurred during the Early Cretaceous: a basaltic magmatism responsible for the accumulation of the Serra Geral Formation (Southeastern Brazil), at 133 Ma. This event is associated to the node 55 of Figure S4.

The second vicariance event is the complete opening of the central Atlantic and the separation of Africa from South America. This event was associated to *Hamadachelys* (Cenomanian of Morroco) sister-group relationships with Podocnemididae, which the basal members are form the Turonian-Coniacian of Argentina and Maastrichtian of Brazil, respectively, *Portezueloemys* and *Bauruemys* (Figure S4, node 67) [19].

At the time of previously publication [19] *Dirqadim*, *Euraxemys*, and *Laganemys* were not described yet. Thus, two other sister-group relationships between northern African and northeastern Brazilian pelomedusoids species can be now associated with the complete opening of the central Atlantic and the separation of Africa from South America: the euraxemydids *Dirqadim* (Cenomanian of Morocco) + *Euraxemys* (Aptian-Albian of Brazil) (Figure S4, node 66) and the araripemydids *Laganemys* (Aptian-Albian of Niger) + *Araripemys* (Aptian-Albian of Brazil) (Figure S4, node 62).

So, the results of the presented analysis confirm and provide more robust evidence about the previous biogeography scenario.

REFERENCES

1. Maffizzoni A. F. 2002 Alguns aspectos da paleoictiofauna e do paleoambiente do Aptiano Inferior da Bacia de Sergipe-Alagoas. *Arq. Mus. Nac.* **60**,121-126.

2. Campos Neto O. P., Souza Lima W., Cruz F. E. G. 2007 Bacia de Sergipe Alagoas. *Bol. Geoc. Petrobras* **15**(2), 405-415.

3. Antonioli L., Dino R., Gallo V. 2009 Palinomorfos barremianos e peixes associados em sedimentos da Formação Morro do Chaves, Bacia de Sergipe-Alagoas, Nordeste do Brasil. In: XXI Congresso Brasileiro de Paleontologia: A paleontologia e os eventos globais, Belém. *Livro de Resumos*, *SBP*, p. 22.

4. Joyce W. G., Parham J. F., Gauthier J. A. 2004 Developing a protocol for the conversion of rank-based taxon names to phylogenetically defined clade names, as exemplified by turtles. *J. Paleontol.* **78**(5), 989-1013. (DOI: 10.1666/0022-3360(2004)078<0989:Dapftc>2.0.Co;2)

5. Gaffney E. S., Tong H., Meylan P. A. 2006 Evolution of the Side-Necked Turtles: The families Bothremydidae, Euraxemydidae, and Araripemydidae. *B. Am. Mus. Nat. Hist.* **300**, 1-700. (DOI:10.1206/0003-0090(2006)300[1:EOTSTT]2.0.CO;2)

6. Gaffney E. S., Meylan P. A., Wood R. C., Simons E., Campos D. A. 2011 Evolution of the Side-Necked Turtles: The family Podocnemididae. *B. Am. Mus. Nat. Hist.* **350**, 1-238. (DOI: 10.1206/350.1)

7. Gaffney E. S., Jenkins Jr. F. A. 2010 The cranial morphology of *Kayentachelys*, an Early Jurassic Cryptodire, and the early history of turtles. *Acta Zool. (Stockholm)* **91**, 335-368. (DOI:10.1111/j.1463-6395.2009.00439.x)

8. Gaffney E. S., Krause D. W. 2011 *Sokatra*, a new Side-Necked Turtle (Late Cretaceous, Madagascar) and the diversification of the main groups of Pelomedusoides. *Am. Mus. Novit.* **3728**, 1-28. (DOI: 10.1206/3728.2)

9. Joyce W. G., Sterli J. 2012 Congruence, non-homology, and the phylogeny of basal turtles. *Acta Zool. (Stockholm)* **93**, 149-159. (DOI: 10.1111/j.1463-6395.2010.00491.x)

10. Joyce W. G., Parham J. F., Lyson T. R., Warnock R. C. M., Doneghue, P. C. J. 2013a A divergence dating analysis of turtles using fossil calibrations: an example of best practices. *J. Paleontol.* **87**(4), 612-634. (DOI: 10.1666/12-149)

11. Joyce W. G., Schoch R. R., Lyson T. R. 2013b The girdles of the oldest fossil turtle, *Proterochersis robusta*, and the age of the turtle crown. BMC Evol. Biol. 13, 266-274. (DOI: 10.1186/1471-2148-13-266)

12. Sterli J., Pol D., Laurin M. 2013 Incorporating phylogenetic uncertainty on phylogeny-based palaeontological dating and the timing of turtle diversification. *Cladistics* **29**, 233-246. (DOI: 10.1111/j.1096-0031.2012.00425.x)

13. Sterli J. 2010 Phylogenetic relationships among extinct and extant turtles: the position of Pleurodira and the effects of the fossils on rooting crown-group turtles. *Cont. Zool.* **79**, 93-106.

14. Gaffney E. S., Rich T. H., Vickers-Rich P., Constantine A., Vacca R., Kool L. 2007 *Chubutemys*, a New Eucryptodiran Turtle from the Early Cretaceous of Argentina, and the Relationships of the Meiolaniidae. *Am. Mus. Novit.* **3599**, 1-35. (DOI: 10.1206/0003-0082(2007)3599[1:CANETF]2.0.CO;2)

15. Sereno P. C., ElShafie S. J. 2013 A New Long-Necked Turtle, *Laganemys tenerensis* (Pleurodira: Araripemydidae), from the Elrhaz Formation (Aptian–Albian) of Niger. In Morphology and Evolution of Turtles (eds. Brinkman D, Holroyd P, Gardner J), pp. 215-250. Springer, Vertebrate Paleobiology and Paleoanthropology Series. (DOI: 10.1007/978- 94-007-4309-0_14)

16. Gaffney E. S., Krause D. W., Zalmout I. S. 2009 *Kinkonychelys*, a new Side-Necked Turtle (Pelomedusoides: Bothremydidae) from the Late Cretaceous of Madagascar. *Am. Mus. Novit.* **3662**, 1-25. (DOI: 10.1206/672.1)

17. Goloboff P. A., Farris J. S., Nixon K. C. 2008 TNT, a free program for phylogenetic analysis. *Cladistics* **24**, 774-786. (DOI: 10.1111/j.1096-0031.2008.00217.x)

18. Nixon K. C., Carpenter J. M. 1996 On simultaneous analysis. *Cladistics* **12**, 221-241. (DOI: 10.1111/j.1096-0031.1996.tb00010.x)

19. Romano P. S. R., Azevedo S. A. K. 2006 Are extant podocnemidid turtles relicts of a widespread Cretaceous ancestor?. *S. Am. J. Herp.* **1**, 175-184. (DOI: 10.2994/1808-9798(2006)1[175:AEPTRO]2.0.CO;2)

20. Broin F. 1988 Les Tortues et le Gondwana. Examen des repports entre le fractionnement du Gondwana et la dispersion géographique des Tortues pleurodires à partir du Crétacé. *Stud. Geol. Salm., Studia Palaeocheloniologica* **2**(5), 103-142.

DATA MATRIX

Basic SS language. Nexus and TNT files available at Morphobank (Project #1194). For characters description check [5,15].

xread
175 49
Outgroup
000000[01]0000000000[01]000000000000000000000000000000000000000000000000000000000000000000[01]0000000000000000000
000000000000000000000000000000000000????????????????????????????????????
Proganochelys
0000001000000000000000000000000000000000000000000000000000000000000000000000000000?0000000000000000000
000000000000000000000000000000000000????0000001000000000000000000?0000
Australochelys
??0?00???00??0?????????000???0?0?0000??0?1???1????0000?000?01010111???00???????1000????0???????010??????00?11?1???
???
Palaeochersis
??0?00?0??00?0??0???0??????????0??0??????????1????00000??0?0111111100000???????1000????0???????010?0????1??11?10??
???0?????0??00000?00000??0??????????0???????000?00???00???000
Kayentachelys
0110000110000000000100000000010010000000000001110000300000000001111111000010000000111100001?0100001110001001100
11021000000010?1000000110000?000200011010002001020010101000000?000004
Selmacryptodira
[01]110[01][01]01[01]0[01]00[01][01]00[01]10000000001[01][01]10[012]0[01][01]0[03]000011100[01]0[23][01][01]00000001111
111000010410[01]0[01]11[12]1000[01]10010000111[01]001001101102100000[01]0100[01]0000001100001000[012]2[0123]00[01][
12][01][12][01]0[01]2[01]0[01]02001[01]101?0000[01]00[01]0[01][014]
Chelidae
0110000010[01]0000010100000000010001000[01]0240000011010032000201011111111100110030[01]010112100001[01]11000001
10001001201102100000[01]0010011[01]1222111111110[123]2[01234][12][01][013][234][123]2[12][12]0210[01]120[13]11111?[01
][01]01101[01]111
Pelomedusidae
111100[01]01000011010100000000010001000[01]00300[01]01212100320002010111111110011003010101121100011110000011000
000[01]12011021100[01][01]001001101212111111111[12]2[123]1002[12][12][01]2[01]2100120[12]11111000011010[01]11
Sokatra
1111000??000?11?1010000000010????0010?30000????10032000201?1111111100110070?0?0111104????110010011100021??11
??1???
Araripemys
11110?0010100110101000000000101010000000033000??1?10130000201011111111001100300110 11[12]1000010110000011000000 1
3?1102110001001101111210111111111114202022[01]?0202111120301111000?21?12015
Laganemys
11110000100012101010000000001110100000000033000??1?10130000201011111111001100300110111111?00?01100000110000 0?13?
1102110001000001111210???1???11421?022111212111?2?2011110001?10120?5
Atolchelys
1111??0??01??[12]1??00???0000??010??111??0????1110100?????????????????11110?41101?????020110????210?11??1?11401?0
2?????????????????????1?????????????????????????2111??1???11?????1?
Euraxemys
111100001000101010100000000010001000100300000110100300001010111111111001100 41?0101111021010110010011100000 11?
11?2110001001001111212111111111120?00212?2?2100120211111100?011011011
Dirqadim
111100001000100010100000000010101000100300000??1?10030000101011111111001100 41?1101111021010110010011100000 11?
11?2??
Podocnemididae
1111000010001010[12]0100[01]00000100[01]10[012]0[01]00300001[12]1[02]10032000[012]011111111110111004100101121000
11111002001110000112011021 1[01]000[01]1101211121211111111 1[12]2[123]1002[23]1[12][012][01]2100120211111[01]11[01]
11010011
Hamadachelys
1111000010001010?0100000000010001?00000300001110100320002011111111110111004 1?0101121000111?100200111000011 2?
11?2?10000001002???
Brasilemys
??1??????0000???1010000000010????000003??00??1??00300001011111111111011?0041?01?111103011??100200??10000112?11?
2?1000?0010?2???1?????1?1??12?11002222?121001???????????????????
Cearachelys
1111000010000210101100000000110?101000100000?1101013[02]000001101111111[01]0110041101111111110110?1102[01]01110
11011101102?110101010001?12?2???111111[13]20?0121[12]?2?2100120211111000011010014

Galianemys_emringeri
1111[01]000100002101012000000111011010001000000??1?1013110100110111111110110041101111110101101110210111011011
101102???
Galianemys_whitei
11110000100002101012000000111011?100010000001101013110100110111111100110041?0111111010110111020011101101110
1102???
Kurmademys
11110000100001111010000000110011010001300001?1?101311012011111111111011002010111121010110?10021011110101120
11?2??10101010001??2??11?111?1112311023112121 0012?2?????011111??0?11
Kinkonychelys
1111000??000?1??1010??0???11?????1000?30000??????1311012011011111111101100201?1??121110110?10022011110101120110
2???
Sankuchemys
11110???10??011??010??0?????001??1010??00?011101?????????111111111001?0?41?0??11?1?10110?1??210??1????112?11?2?
??
Foxemys
111110001001001010100001001110110200010001001101010131000011101111111120110041?011111111010110?111210??11010112?
11?2?110101101101112??11?111111222[12]10222121210012?211111111[01]11010111
Polysternon
111110?0100?001??010000?00??1011?100010000???1??013100001111111111201?0041?0?1111111010110?1??200??1101?112?11
?2?????0???????????????1?1??1222[12]10222121210112?21111011111010113
Araiochelys
111101101001001??01000110011112201100?100000110?0111100011101111111100110011?1?11121110110?1112001110101111?
11?2?11110010110?????????1??????????043212121???2?2?1????10111??0?11
Zolhafah
11111?00100??????10??1???1??01102100??0000011010131100?11101111111100??0051?0101121?1?110?11?200??1101?1110110
2???
Rosasia
11111000100100?01010001???11?021021001100000110101?11?001110111111110???041?01111?1??0?1??111200??110??111011
02?????????????????????1????1122?10221?2?2101???2?11111000?10?0011
Bothremys_cooki
111111101011???120100?1???11?12202101??11100110101????????????????1001?0???101??????????1????????????????1?11102??
11101???1??
Bothremys_maghrebiana
1111111010110011201000110[01]1111220[12]10[01]1111[01]00110101111000111011111110011001111111121110110111112001
11101[01]21111102?11110[01]10110??
Bothremys_kellyi
11111110101?001??0100?11001111202101?1100???1??01111000111011111111100??0?51?0?1112111011??11?2001?11011211?11
?2???
Bothremys_arabicus
??1?1??0?01????12??0??1????1??1??210?????0?0110?01?11?00?1101111111001??011???1?12?110110?11?20???110??211?11?2?
??
Chedighaii_hutchisoni
11111110101100112010000100111?1??20011000001110101?1100011101111111100110011?0111121110110?1112001110011211?
11?2???
Chedighaii_barberi
11111??0101?????201?0?010?1???2??100???0000??1???1111?0011?0111?11100???011?0?1?121?10110?111200??1101121111102
??11101101?01112????11111111232102211212101120211111100110?0011
Taphrosphys_sulcatus
1?1100???00?20???01????0111?00?11???????0????1????311100?111111111100???15110?0112111001011112001111010112?1112
????????????1112??1111111111122210222[12]212100120211111110?211?1012
Taphrosphys_congolensis
111100?0100?201??0101?00111200?11000001000???1?1?0?11?0011111111111001?0?51?0?01121110110?111200?111010112011
02??000?0?????????????????????222??22???1?10????2??1?1?1012?1???12
Taphrosphys_ippolitoi
111100?0100??01??01011001112?01110000010001??1?1?031110011111111111?0110151?0101121110110?1??2001111010112?1
112???
Azabbaremys
11110000100000101010010000121101000000010001111111021100011101111111100??0011?0101121110110?11120011110102110
1102???
Acleistochelys
11110?001000???0101001110012?01200110?10001111111031100011101111111201?0051?111?121110110?1112001111010211?1
1?2???
Labrostochelys
11110110100?201?10101?0111??0122000000120010110100111100111011111111001100[16]0?1101121110110?111200?11101021
1?11?2???

Phosphatochelys
1111000011002011111001001112001210001023000??1?11031110011101111111001101111?0101121110110?1112001111010[12]1
2?11?2???
Ummulisani
1111010?110020?0?110010011120012100010230000?????02111001111111111001?01[16][01]?[01]100121110110?11120011110
?0112?1??2???2111111100211?1?12
Rhothonemys
111100?0?00??01??1100???1?12?1?2?0001??300???1????311100????1111111????0????0?01121???????11???0?????1??1??11????
0000010?10???
Nigeremys
1?1100???000001??010??0????1?01100000??000?0110?1?2110001112111111201?00???1??1121??0?1??1??200??110?0214?11?2
???0???
Arenila
??110????00?????10100?0???11?0???0000??000001101?0211?0??1121111111201???41?11??12111?110?111200??1?010214?11??
??
Proterochersis
???
???????????11110?0?1??0????00?10000?0010000000011001010
Platychelys
??????????????????1???
???1001211?11111?00202010[01][02]1011000011111111000011011010
Notoemys
??1??1?11111?????????????11?1????1?11????01??????????1??2???????
?????1?012???1111?10020?010111?02000011111????00011??001?
Dortoka
???
???1?1221???1111?[01]12[01]1100[13]0221210012?311111000?112?0016;