

# Minoan and Finno-Ugric Regular Sound Changes Discovered by Data Mining

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**Abstract**—Cognate words within language families derive from common protowords and are transformed by regular sound changes. The demonstration of regular sound changes between pairs of languages is a major tool in proving that they belong to the same language family. This paper applies association rule data mining to identify regular sound changes between Finno-Ugric languages and Pre-Greek, which Robert Beekes identified to be a single language, which can be called the Minoan language.

**Keywords**—association rule data mining, Finno-Ugric, language family, Minoan, Pre-Greek, regular sound change, Weka

## I. INTRODUCTION

Comparative linguistics aims to study the history of languages and to reconstruct protolanguages of various language families, such as the *Indo-European* language family, which includes English, French, German, Greek, Latin, Sanskrit and hundreds of other languages, and the *Finno-Ugric* language family which includes Estonian, Finnish, Hungarian and dozens of other languages [6, 9, 10, 11].

Etymological dictionaries list the origin of each word. For example, the *Etymological Dictionary of Greek* (EDG) by Beekes [2] classifies each ancient Greek word according to labels such as the following: IE (Indo-European), IE? (likely Indo-European), ? (no good etymology), PG (Pre-Greek) and PG? (likely Pre-Greek). Pre-Greek words are those that were borrowed by the Greeks from some earlier language that existed in present day Greece. The EDG lists a total of 1106 Pre-Greek words. Beekes [3] shows the essential unity of Pre-Greek, meaning that the Pre-Greek words were borrowed from the same non-Indo-European language. This unique Pre-Greek language was the Minoan language, which is preserved in the Linear A [7] and the Cretan Hieroglyphic scripts [13]. Linear B, the successor of Linear A, is the earliest Greek script used by the Myceneans, who borrowed much from the Minoans [5].

The *Uralisches Etymologisches Wörterbuch* (UEW) edited by Rédei [15] contains a reconstruction of Proto-Finno-Ugric words. The UEW classifies 626 basic Hungarian words as cognates with words in other Finno-Ugric languages.

The goal of this paper is to answer the following question: Is Minoan a Finno-Ugric language?

The rest of this paper is organized as follows. Section II reviews the concept of regular sound change rules in linguistics. It also describes an experiment of applying association rule data mining to a set of hypothetical cognate words between Finno-Ugric languages and Pre-Greek. Section III discusses the results

by giving examples of regular sound changes and explaining the implications for the translation of Minoan inscriptions. Finally, Section IV gives some conclusions and describes future work.

## II. DATA MINING REGULAR SOUND CHANGES

Traditionally, comparative linguists reconstruct the phonological history of a language family manually by noticing *regular sound changes*, that is, changes in pronunciation that are commonly occurring between pairs of *cognate words*, which are words that are assumed to have derived from a common unknown protoword. For example, word initial /k/ before a back vowel in Finnish regularly changes to /h/ in Hungarian as shown by the following examples [9]:

Proto-Finno-Ugric	Finnish	Hungarian	Meaning
*kala	kala	hal	fish
*kota	kota	ház	house
*kunta	kunta	had	group of people

Revesz [20] gave a data mining algorithm that can generate regular sound change laws given a set of hypothetically cognate words as an input. Therefore, we collected pairs of PG and Finno-Ugric words that seemed potentially cognate from the EDG and UEW etymological dictionaries. Table I lists 159 Pre-Greek words, out of which 133 are labeled PG and 26 PG? by the EDG. To all of these words, we found hypothetically cognate words that appear in UEW except five words, which we added to the list of Finno-Ugric words. In Table I the first column identifies the UEW entry number or ‘new’ if it does not appear there. The second column is the Proto-Finno-Ugric or Proto-Ugric word reconstructed by UEW except for the new entries. The Proto-Finno-Ugric layer is shared by all the Finno-Ugric languages, while Proto-Ugric is shared by Hungarian, Khanty, Mansi and, hypothetically, Minoan. The third column is our reconstruction of a Proto-West-Ugric form, which is a layer we assume to be only shared by Hungarian and Minoan. The next five columns give the hypothetical cognate words in Hungarian, Mansi (or if it is not available, then the closely related Khanty), Zyrian, and Minoan, and the EDG classification of the Minoan word. Finally, the last two columns give the meaning of the Hungarian and the Minoan words.

We entered a representation of the consonants of the collected list of words into an ARFF file and applied the Weka association rule data miner to help in the discovery of regular sound change rules. The last columns of Tables II and III show the Minoan regular sound changes that were identified for the word initial consonants and the medial consonants, respectively.

TABLE I. COGNATE FINNO-UGRIC AND MINOAN WORDS

UEW	Proto-FU or Ugric	Proto- West-Ugric	Hungarian	Mansi K=Khanty	Zyrian	Minoan	EDG	Hungarian Meaning M = Mansi Meaning	Minoan Meaning
9	<i>al3</i>	<i>al3</i>	áld	alil		ὄλ-βο3	PG	bless, spell magic	prosperity, bliss
15	<i>aña</i>	<i>aña</i>	ángy	ḡnye	oña	γαία	PG	older relative's wife	earth goddess
1730	<i>ämp3</i>	<i>ämp3</i>	ëb	ämp		ἱαμβο-3	PG	dog	metric meter
51	<i>éapp3</i>	<i>éapp3</i>	csap		éapki	σφά-ζω	PG?	to hit	slay, slaughter
49	<i>éađa</i>	<i>éađa</i>	szalad		éual-	σαῦλο-3	PG	rust > run	walking [of animal]
1737	<i>éðkk3</i>	<i>éðkk3</i>	szik	šäχ		σαυκό-v	PG	salty, dry	dry
76	<i>čukkk3-r3</i>	<i>čukkk3-r3</i>	csokor		éuker	σίγραι	PG	herd, group, bouquet	wild swine
80	<i>čuppp3</i>	<i>čuppp3r3</i>	csupor		éib'eg	στυρί-3	PG	(birch bark) vessel	basket
1744	<i>čitt3</i>	<i>čitt3</i>	süt	šit		σίτυ-βο3	PG	to bake, shine (sun)	cauldron
1744	<i>čitt3</i>	<i>čitt3</i>	süt	šit		στα-θεύω	PG	to bake, shine (sun)	roast, fry
132	<i>elä</i>	<i>elät3</i>	él > élet	jält	ol	Εὐλειθωα	PG	to live > life	goddess of birth
new	<i>ešk3</i>	<i>ešk3</i>	üszög	eškëη		Λογε-λάτας	PG	blazing	epithet of Apollo
139	<i>ewkk3</i>	<i>ewkk3</i>	ük, ik	ëkə		άκκώ	PG	great-grandmother	bogey, vain woman
152	<i>ir-kä</i>	<i>ir-kä</i>	ër			ἥρω3	PG	man	lord, hero
new	<i>išt3</i>	<i>išt3</i>	isten	išti		σάτυ-ρο3	PG	(sun)god, M to burn	satyr
190	<i>jon33</i>	<i>jow-ti</i>	ív	jowt		Ἰαπετός	PG	bow   piercer, cf. ἱαφέτης=archer	
195	<i>juke</i>	<i>juke</i>	i	äj	ju	ῥστ-ιακκό3	PG	to drink	drinking cup
227	<i>kakta</i>	<i>kat</i>	két	kit		Καδ-μίλο3	PG	two	Kadmilus (2 boys)
227	<i>kakta</i>	<i>katta</i>	két > kettő	kit		κόττα-βο3	PG	two	game with 2 vases
228	<i>kala</i>	<i>kala</i>	hal	χāl		καλλα-ρίας	PG	fish	cod fish
new	<i>kal3</i>	<i>kal3</i>	halk	ka'nä		χολο-βός	PG	quiet; M sound, cry	curtailed, short
232	<i>ka'w3</i>	<i>ka'w3</i>	hályog	χα'əp		χάδα-μός	PG	cataracts, membrane	blind
249	<i>kar3</i>	<i>kar3</i>	harap		kuréj	χάρα-βο3	PG	to bite	prickly crustacean
1773	<i>kāñč3</i>	<i>kāñč3</i>	keshed	kañsl		άκιδ-νός	PG	lean; M lose weight	thin cf. σκιδάρων
281	<i>kel-ke</i>	<i>kellem3</i>	këll > kellem		kol	χλεμε-ρός	PG	necessary > pleasant	warm, verdant
new	<i>keñir3</i>	<i>keñir3</i>	kenyér	küör	keñjr	γοῦρο-3	PG	bread, M oven	cake
288	<i>kere</i>	<i>kere</i>	köré		kor	κίρ-βα	PG	around	leather pouch
1776	<i>ki</i>	<i>kil-s3</i>	ki > külső	kānə		κολοσσό-3	PG	out > appearance	statue
300	<i>kič3</i>	<i>kič3</i>	köcsög	küšəm		κισσό-βιον	PG	vessel,	rustic cup
320	<i>kit-ke</i>	<i>kit-l3</i>	köt > kötél	kät		κόλλο-ψ	PG	tie, knit	string peg/screw
320	<i>kit-ke</i>	<i>kit-en</i>	köt > kötény	kät		χιτών	PG?	tie, knit	apron, tunic
322	<i>kiwe</i>	<i>kiwe</i>	kő	kāw		γή	PG	stone	earth
328	<i>koja</i>	<i>koja-päč</i>	héj > külbécs	K köj	keja	κέλυφος	PG	bark, haut > snail	husk/skin, eggshell
339	<i>kola</i>	<i>kola</i>	hal > haló	χōl	kul	Αχιλλε-ύ3	PG	to die > mortal	Achilles
342	<i>kol3</i>	<i>kol3</i>	halok	χāl	colas	κολο-βός	PG	crack, gap to cut tree	curtailed, maimed
341	<i>kol-me</i>	<i>kol-me</i>	három	χūrəm	kujim	κίλ-λίβας	PG	three	three-legged stand
349	<i>kon3</i>	<i>konot3</i>	hanyatt	χonəj		κίνδυ-νο3	PG	on back	bench, bed [backw.]
367	<i>kor3</i>	<i>kor3-s3</i>	horzsol	karšəl	kural	χαράσσω	PG	to scrape	carve, engrave
367	<i>kor3</i>	<i>kor3</i>	horol	karšəl	kural	χίρά-3	PG?	to scrape	chap, crack
439	<i>kðm3</i>	<i>kðm3</i>	homorú > hiú	K kõm		κομμό-μαι	PG?	empty > vain	embellish/adorn self
1790	<i>kðn3</i>	<i>kðn3</i>	könnyű	kinna		κίν-δαζ	PG	light (weight)	easily moved
1780	<i>kuj3</i>	<i>kuj3</i>	hajt	χujt		κολλό-ροβον	PG	to drive, herd;	shepherd's staff
387	<i>kul-ke</i>	<i>kul-ke</i>	halad		kølt	κάλ-πη	PG	move, drift	trot
393	<i>kuma</i>	<i>kuma</i>	homlok	χaməj	kimeš	κύμ-βαχο3	PG	forehead	falling headfirst
393	<i>kuma</i>	<i>kuma</i>	homlok	χaməj	kimeš	κύμ-βη	PG	forehead	head
400	<i>kunta</i>	<i>kunta</i>	had	χōnt		χυδο-μίδ3	PG	army	din of battle
426	<i>kur3</i>	<i>kur3</i>	harag	χor		κῆρ < *kāp	PG	anger, bicker	doom, death demon
426	<i>kur3</i>	<i>karak3</i>	harag	χor		καρκί-νο3	PG	anger, bicker	crab
1784	<i>kur3</i>	<i>kur3</i>	hord > hordó	χart		κρω-σός	PG	to drag, draw; barrel	pail, pitcher, bottle
419	<i>kurná</i>	<i>kurní</i>	horny			χηρα-μός	PG	grooving	hole, cleft, slit
458	<i>lapp3</i>	<i>lapp3</i>	lap	lop	lop	κό-λαφο-3	PG	flat, surface	buffet
1793	<i>läpp3</i>	<i>läpp3</i>	lép	lõp		κό-λαβ-ρο3	PG	to step (in)	dance song
475	<i>lemp3</i>	<i>lemp3</i>	lebég		leb	λάβηξ	PG	to fly	vulture
479	<i>lepp3</i>	<i>lepp3</i>	lep	lëp	leb	λέπω	PG	cover	peel off
480	<i>leše</i>	<i>leš-ti</i>	liszt			ἀλειατα	PG	flour   rice-wheat groats, cf. ἄλιξ [2]	
485	<i>likkã</i>	<i>likkã</i>	lök			λιγά-ξαι	PG	push, shove	throw
485	<i>likkã</i>	<i>likkã</i>	lök			λάξ	PG?	push, shove	with heal or foot

493	<i>lowkk3</i>	<i>lowkk3</i>	lyuk	lōχ		ἄλοξ	PG	hole, crevice	furrow
506	<i>l8</i>	<i>lek</i>	le > lejt			λέχ-ριος	PG	lower part > slide	slanting, cf. λοξός
501	<i>l8h3</i>	<i>l8h3</i>	légy		leḡ	λάττα	PG	a fly	Cretan fly [2] p. 534
504	<i>l8pp3</i>	<i>l8pp3</i>	láp	lūp	lūp	λάπα-θος	PG	drift objects > mud	pitfall for animals
505	<i>l8tt3</i>	<i>l8tt3</i>	lát			λαίθα-ργος	PG	to see	guileful, treacherous
498	<i>luwe</i>	<i>luwe-t3</i>	láb > lábos	lo	li	λέβης, -ητος	PG	leg, bone > tripod	cauldron
new	<i>mak3</i>	<i>mak3</i>	magas	K mōχeη		μακε-δνός	PG	tall	tall
new	<i>mak3</i>	<i>mak3</i>	magas	K mōχeη		μέγα-ρον	PG	tall	temple inner space
1798	<i>malk3</i>	<i>malk3</i>	malát	K māvlij		ἄμαλλα	PG?	willows, shrubs	sheaf
1800	<i>maíć3</i>	<i>maíć3</i>	mese	K moñt'		μῦθο-ς	PG?	tale	word, discourse, tale
1801	<i>mar3</i>	<i>mar3</i>	márt	mürs		μύραι-να	PG	to dip	eel
1803	<i>mäl3</i>	<i>mäl3-k3</i>	meleg	mōltəp		μάλκη	PG	warm	numbness from cold
1806	<i>mär3</i>	<i>mär3</i>	mer	mār		μέρμερο-ς	PG	to dare, risk	difficult, awesome
538	<i>mer3</i>	<i>mer3</i>	mér		murtal	μήρι-νθος	PG	to measure	cord, thread
539	<i>mete</i>	<i>mete</i>	méz		ma	μίτη-ς	PG?	mead	substance of bees
547	<i>mirkk3</i>	<i>mirkk3</i>	mérëg			μάργο-ς	PG	poison, anger	mad, furious
569	<i>m8l3</i>	<i>m8l3</i>	mál			μαλ-θακός	PG	peel off, wash off	weak, tender, soft
1814	<i>m8l3</i>	<i>m8l3</i>	méltó	mel-		μολο-βρός	PG	fit (shoe) > worthy	scornful
566	<i>mura</i>	<i>mura</i>	mar	mor		μαρά-σσαι	PG	bite, break	dogs, swine
566	<i>mura</i>	<i>mura</i>	mar	mor		μάρ-πτω	PG	bite, break	catch, seize
590	<i>näke</i>	<i>näkti</i>	néz	niyl		νυκτά-λωπος	PG	to look; dream	seeing loss
598	<i>niñä</i>	<i>ni</i>	ne	nē	ñin	Ελέ-νη	PG	woman	mother of life
598	<i>niñä</i>	<i>ni</i>	ne	nē	ñin	νύ-μωη	PG	woman	nymph [nu + lemp3]
639	<i>ñor3</i>	<i>ñor3</i>	nyirok	ñār	ñur	Νηρε-ύς	PG?	moist place, swamp	Gaia and Pontus' son
648	<i>ñuη3</i>	<i>ñuη3</i>	nyugsz-	ñünt		νῶκα-ρ	PG	rest	slumbering
648	<i>ñuη3</i>	<i>ñuη3</i>	nyugsz-	ñünt		νωχε-λής	PG	rest	slow, dull, sluggish
658	<i>oćt3r3</i>	<i>oćt3r3</i>	ostor	ōstər		ὕστρι-χίς	PG	whip	hedgehog, whip
1873	<i>8j3</i>	<i>aj-t3</i>	ajtó	ajt		αἰδω-σσα	PG	door	walls of a hall/court
1873	<i>8j3</i>	<i>aj-t3</i>	ajtó	ajt		αἰθου-σα	PG	door	portico
681	<i>pać3</i>	<i>pać3</i>	fasz			πόσ-θη	PG	penis	penis
698	<i>pal3</i>	<i>pal3</i>	bal	paľfan		φαῦλο-ς	PG	left	bad, unfit, ill, mean
708	<i>par3</i>	<i>par3</i>	farag	pār		φορια-μός	PG	to carve, hollow out	chest, trunk
710	<i>pata</i>	<i>pata</i>	fazék	püt		πίθο-ς	PG	pot, kettle	wine jar
687	<i>pað3</i>	<i>pað3</i>	fäl	K päl		πλα-στή	PG?	wall	(clay) wall
711	<i>päč-k3</i>	<i>päč-k3</i>	fecske		pišci	ράσσα	PG?	swallow (bird)	wood-pigeon
717	<i>päj3</i>	<i>päj3-r3</i>	fejér			φαλό-ς	PG	white < shiny	white
717	<i>päj3</i>	<i>pän3</i>	fejér > fény			πανός-ς	PG?	light	torch
722	<i>pälä</i>	<i>pälä-k3</i>	fele	K pelək	peľ	παλλακή	PG?	one side, half, wife	concubine
729	<i>päñe</i>	<i>päñe</i>	fej	pāñk	pon	φαλά	PG	head	face, countenance
729	<i>päñe</i>	<i>päñe</i>	fej	pāñk	pon	πήλη-ξ	PG	head	helmet
735	<i>peje</i>	<i>pez</i>	fő > főz			ἔψω	PG	to heat, simmer cook	boil
739	<i>pele</i>	<i>pele-lm</i>	fél > *félelm	pil	pol	πελεμί-ζω	PG?	to fear > fear, worry	shake, tremble
738	<i>pele</i>	<i>pele</i>	fél			πύλη	PG?	pole   one wing of pair of double gates	
751	<i>per3</i>	<i>per3</i>	bör	K pēr		φορί-νη	PG	skin, birch tree bark	hide
1825	<i>pić3</i>	<i>pić3</i>	füst	pošəm		νό-λος	PG	smoke	soot
1825	<i>pić3</i>	<i>pić3-t3</i>	füst	pošəm		νόθο-ς	PG	smoke	ashes
1826	<i>pil3</i>	<i>pil3</i>	fül	pāl		φλε-ν	PG?	to burn	to burn
759	<i>piðe</i>	<i>piðe</i>	fël	pält		φιάλη	PG	high, long	flat vessel
789	<i>pola</i>	<i>pola</i>	bogyó	pol	pul	φήλη-ξ	PG	berry	wild fig
842	<i>p8jć3</i>	<i>p8jć3</i>	fejsze	pächt		φάσ-γανον	PG	axe	sword
1832	<i>p8l3</i>	<i>p8l3</i>	folly	polšit		πλα-τυγίζω	PG	to flow	splash
823	<i>p8r3</i>	<i>p8r3</i>	fér		pīr	πήρα	PG?	to fit in	leather bag
766	<i>pülk3</i>	<i>pül3</i>	fürdik	päyl	pilši	πύελό-ς	PG	to bath	bathtub
821	<i>pur3</i>	<i>pur3-k3</i>	far > farok	K pīr		φορκό-ν	PG	behind > tail [wolf]	white/grey, wrinkled
826	<i>puš3</i>	<i>puš3-l3</i>	foszlik	posl-		φάλλω	PG?	peel off feather	pluck
829	<i>puw3</i>	<i>puw3-k3</i>	fa > fák	pā	pu	φάκε-λος	PG	tree > trees	bundle of sticks
850	<i>rakk3</i>	<i>rakk3</i>	rak			ἄρακι-ς	PG	to put, make	bowl, pan
1840	<i>r8ηk3</i>	<i>r8ηk3</i>	rúg	K ruñk		ἐρέχ-θω	PG	to kick, Kh wade	rend, break
868	<i>r8pp3</i>	<i>r8pp3-t3</i>	rëpít	rëp		ρίπτω	PG?	to fly, throw, shake	
866	<i>r8t3</i>	<i>r8t3</i>	rút	K rätək		ρόδι-γγες	PG	ugly	bruise
1844	<i>säkr3</i>	<i>sär3</i>	szőr	sšr		σι-σύρα	PG	fur, cf. sokkEst. 'goat'	goat's fur cloak

1854	<i>sðr3</i>	<i>sðr3</i>	szár	sor		σύρι-γξις	PG	leg, stem, stalk	pipe-like objects
951	<i>šāṅk3</i>	<i>sāṅk3</i>	segg	sðṅk		ισχίο-v	PG	arse, hip	hip-joint
956	<i>šēppā</i>	<i>seppā</i>	szép			σοφία	PG?	beautiful	clever
964	<i>šilmā</i>	<i>silmā</i>	szem	šām	šin	ὀφ-θαλμός	PG	eye	eye
988	<i>šurwa</i>	<i>surwa</i>	szúr			σαρ-γάνη	PG	to poke, stab	plaited basket
988	<i>šurwa</i>	<i>surwa</i>	szúr			σύρι-κος	PG	to poke, stab	basket
996	<i>šanka</i>	<i>anka</i>	ág			ἀκ-ρεμών	PG	bough	bough
1000	<i>šār3</i>	<i>ār3-ket</i>	ér > ereget	tārt	šerged	Ἐρεχθε-ύς	PG	to reach, let go	Erechtheus
886	<i>šāwnā*</i>	<i>ānā</i>	őn		šin	ὄνο-ς	PG?	fish type	cod-like fish family
1014	<i>šur3</i>	<i>ur3</i>	arat, irt			ἄρη-ς	PG	cut, divide, eradicate	war-god
1745	<i>ḡaṇ3</i>	<i>aṇ3</i>	ág	taw		ἄγ-voς	PG?	bough, branch, tree	withy tree
910	<i>ḡuð3*</i>	<i>uð3</i>	ujj	tuʿa		δάκ-τυλο-ς	PG	finger	finger δέκα 10 -τύλη
910	<i>ḡuð3*</i>	<i>uð3</i>	ujj	tuʿa		τύλη	PG	finger	nail, peg
1857	<i>tal3</i>	<i>tal3</i>	tál	tül		τύλλο-ς	PG	plate	box, chest [cf. τύλη]
1026	<i>tara</i>	<i>tara</i>	tár		taral-	κι-θάρα	PG	open [door, arms]	lyre: play open-arms
1037	<i>tālwā</i>	<i>tālwā</i>	tél	tšl	teḷ	Θάλ-πω	PG	winter	to warm
1859	<i>tāṇ3t3</i>	<i>tāk3z</i>	tegez	tāwət		τόξο-v	PG	quiver	quiver
1860	<i>tār3</i>	<i>tār3-m3</i>	tér > terem	K tirəṇ		τέραμ-να	PG	space, room, square	house, residence
1860	<i>tār3</i>	<i>tār3</i>	tér > terít			τρό-γω	PG	set table < to eat>	to gnaw, eat
1046	<i>tem3</i>	<i>terp3</i>	töm > törp-ül			τρέφω	PG	to shrink	to cause to curdle
1046	<i>tem3</i>	<i>ter-emp3</i>	töm > tereb*			θρόμβο-ς	PG?	stocky > spreading	clot, curd
1049	<i>terä</i>	<i>terä</i>	tör	ter		τύρ-αννος	PG	dagger, sword	tyrant
1066	<i>tor3</i>	<i>tor3</i>	dorgál			δρ-ηστήρ	PG	scold	laborer < whip
1070	<i>tow3</i>	<i>tow-lox</i>	tó	lōx	tī	θάλα-σσα	PG	lake, M bay	sea
1865	<i>tōmp3</i>	<i>tōmp3</i>	domb	tomp		τύμβο-ς	PG	hill	burial mound
1085	<i>tōrk3</i>	<i>tōrk3</i>	törköly*	tārəy		τέργ-voς	PG	pressed grape, M pine	sprout, twig, fruit
1075	<i>tulka</i>	<i>tulka</i>	toll	towl	tīl	τύλη	PG?	feather	bulge, callosity, nail
1862	<i>tult3</i>	<i>tult3</i>	táltos	K tolt		θάτα-ς > θής	PG	magician, diviner	sacrificer
1863	<i>tur3</i>	<i>tur3-k3</i>	torok	tor		θώραξ	PG	throat	cuirass, trunk, chest
1864	<i>tüw3t3</i>	<i>tüz</i>	tüz	tšwt		θός-θλα	PG	fire; 'tüz-tál' cf. tál	Bacchic orgy tool
1096	<i>utka</i>	<i>utu</i>	út > utazó	āxt		Ὀδν-σσεύς	PG	road, path > traveler	Odysseus
1106	<i>wajće</i>	<i>wajće-k3</i>	vöcsök	wās	vež	βασκά-ς	PG	duck	duck
1110	<i>walka</i>	<i>walka</i>	vál	wojl		βλά-βη	PG	to separate, descend	damage
1110	<i>walka</i>	<i>walka</i>	vál	wojl		βλαι-σός	PG	to separate, descend	bent, distorted
1136	<i>wekk3</i>	<i>wekk3</i>	vékony		veknī	βῆκα	PG?	thin	vine on trees
1139	<i>weńć3</i>	<i>weńć3</i>	össze		vić	βυθός-ς	PG	all, together   depth of sea; βυθόν=crowd	
1154	<i>witte</i>	<i>itte</i>	öt	at-lāmtēp	vit	Ἀτ-λαντος	PG	5; M 5-part+āsmā 'cushion' > bear leg   Atlas	
1161	<i>wolka</i>	<i>wolka</i>	váll	wojləp		βαλ-μός	PG	shoulder	breast
1144	<i>wōre</i>	<i>ōre</i>	orr	wōrnə	veṛ	ρί-ς	PG?	nose	nose
1144	<i>wōre</i>	<i>wōre-m3</i>	orr > orom	wōrnə	veṛ	ὄρυμ-ος	PG	nose > mountain	altar
1180	<i>wðn3</i>	<i>wðn3-k3</i>	vén > vének		vener	ράναξ, ἄναξ	PG	old > the old people	lord, ruler

TABLE II. REGULAR SOUND CHANGES FOR WORD INITIAL CONSONANTS

	Proto-FU	West-Ugric	Finnish	Hungarian	Mansi	Zyrian	Minoan
1	č	č	h	s, cs	š, s	č	σ
2	ć	ć	s	cs, s, sz	ś, s	ć, ź	σ
3	j	j	j	j, gy, Ø	j	j	ι
4	k	k	k	k, h	k, χ	k, g	κ, χ, γ
5	l	l	l	l	l	l	λ
6	m	m	m	m	m	m	μ
7	n	n	n	n	n, ḥ	n, ḥ	ν
8	ń	ń	n	ny	ń	ń	ν
9	p	p	p	f, b	p	p, b	π, φ, ψ [only before /s/]
10	r	r	r	r	r	r	ρ
11	s	s	s	sz	s	s	σ
12	ś	s	s	sz	s	ś	σ
13	š	Ø	h	Ø	t	š	Ø
14	ḡ	Ø	h	Ø	t	š	Ø
15	t	t	t, s	t, d	t	t	τ, θ, δ
16	w	w	v, Ø	v, Ø	w, Ø	v	β, φ > Ø

TABLE III. REGULAR SOUND CHANGES FOR MEDIAL CONSONANT

	Proto-FU	West-Ugric	Finnish	Hungarian	Mansi	Zyrian	Minoan
1	č	č	s	cs, s, gy	s	š	σσ, ψ [only after /p/]
2	ć	ć	s	cs, s, sz, gy	ś, s	ž	σ
3	δ	δ	t, d	l, Ø	l	l, Ø	λ
4	δ'	δ'	t, s, d	gy, j	l'	l'	λ
5	j	j	j, i, Ø	j, gy, Ø	j, Ø	j, Ø	λ, λλ, Ø
6	k	k	k, Ø	Ø	w	Ø	κ, κκ, γ, χ
7	kk	kk	kk	k	k	k, g	κ, κκ, γ, χ, ξ [only before /s/]
8	kt	t, tt	ht	t, tt	t	k	δ, κτ, ττ
9	l, ll	l	l	l	l	l	λ, λλ
10	lk	lk		ll	wl	l	λ, λλ
11	lt	lt		lt	lt		τ
12	l'	l'	l	gy, ly	l'	l'	δ
13	m	m	m	m, v, Ø	m	m	μ, μμ
14	mp	mp		b	mp		μβ, ωβ
15	n	n	n	n, ny	n	n	ν
16	η, ηk	η, ηk	Ø, v	Ø, v, g	η, ηk, Ø	Ø, m, n, h	κ, γ, χ
17	nt	nt	nt, nn	d	nt	d	δ
18	h	h	n	ny	h	h	ι
19	hc	hc		s	hs		δ, ττ, θ
20	p	p	p, v	v, Ø	p	Ø	φ
21	pp	pp	p	pp, p	p	p	π, φ, β [before ρ]
22	r	r	r	r	r	r	ρ
23	s	s	s	sz	t'	z	σσ, ψ [only after /p/]
24	š	š					σ
25		št					τ
26	t	t	t, s	z	t	Ø	δ, τ, θ
27	t	z		z			σ, ψ [only after /p/]
28	tl	tl					λλ
29	tt	tt	t, s	t	t	t, t'	ττ, τ, θ
30	w	w	v, Ø	v, Ø	w, Ø, j	Ø	β [between vowels], Ø
31	wt	wt	v		wt		πτ

### III. DISCUSSION OF THE RESULTS

#### A. Finno-Ugric and Minoan Regular Sound Changes

Revesz [21] already presented a table of regular sound changes within the Finno-Ugric languages, including Minoan, using the *International Phonetic Alphabet* (IPA) notation. Now Tables II and III, where the entries show the actual spelling, significantly extend the earlier results. In Tables II and III, the columns describing the regular sound changes for Finnish, Hungarian, Mansi and Zyrian are summaries based on Csúcs [6]. Our contributions are the West-Ugric column and the Minoan column, which represents the Minoan regular sound changes. We give a few examples, where the notation > means derivation, \*W means a hypothetical word W, and W1 ~ W2 means that W1 and W2 are cognate words.

Table II shows that Proto-Finno-Ugric and Proto-West-Ugric word initial /k/ becomes κ or χ in Minoan except in the following case:

kiwe > \*kwi > γή

The 7<sup>th</sup> row in Table III mentions the contraction of /k/ and /s/, which can be illustrated by the following pair ([2] p. 73):

lowkk3 ~ lyuk ~ ἄλοκος > ἄλοξ

Some Minoan compound words preserve the Proto-Finno-Ugric forms better than the cognate Hungarian words. For example, consider the following cognates:

śilmä ~ szem ~ \*ὄφ-σαλμός > ὄφ-θαλμός

Here the Minoan word preserves the /l/ sound, while the Hungarian word does not preserve it. The θ seems to have undergone a transformation due to the preceding φ.

Another Minoan compound word that shows a remarkable preservation of the Proto-Finno-Ugric form is the following:

θuδ3 ~ ujj ~ δάκ-τυλος

The preservation of τ in the above compound word may have affected the preservation of τ in the second component, that is, in the word τύλη.

The Proto-Finno-Ugric and Proto-West-Ugric medial consonants δ and δ' become λ in Minoan.

éaδa ~ szalad ~ σαῦλος  
paδ3 ~ fal ~ πλαστή  
piδe ~ fël ~ φιάλη  
θuδ3 ~ ujj ~ τύλη



The Proto-Finno-Ugric and Proto-West-Ugric medial consonants *ń* becomes *ĩ*, pronounced /j/, in Minoan.

<i>ańa</i>	~ <i>ányy</i>	~ * <i>γń-ańa</i> > <i>γαńa</i> / <i>gaja</i> /
<i>keńir3</i>	~ <i>kenyér</i>	~ <i>γοũρος</i> / <i>gojuros</i> /

The Proto-Finno-Ugric and Proto-West-Ugric medial consonant cluster *ńć* becomes *δ*, *τ*, or *θ* in Minoan.

<i>kāńć3</i>	~ <i>keshed</i>	~ <i>άκιδνός</i>
<i>l8ńć3</i>	~ <i>légy</i>	~ <i>λάττα</i>
<i>mańć3</i>	~ <i>mese</i>	~ <i>μũθος</i>
<i>weńć3</i>	~ <i>össze</i>	~ <i>βυθός</i>

Between two vowels, the Proto-Finno-Ugric and Proto-West-Ugric medial consonant *j* becomes *λ* in Minoan.

<i>koja-päch</i>	~ <i>külbécs</i>	~ <i>κέλũφος</i>
<i>päj3-r3</i>	~ <i>fejér</i>	~ <i>φαλός</i>
<i>päje</i>	~ <i>fej</i>	~ <i>φαλά</i>
<i>päje</i>	~ <i>fej</i>	~ <i>φήληζ</i>

The Proto-West-Ugric *koja-päch* seems to be a compound word with the first part meaning ‘husk’ or ‘shell’ and the second part meaning ‘nest,’ which also is a Proto-Finno-Ugric word.

When the initial consonant of a Proto-Finno-Ugric protoword is *š* or *ʒ*, then the corresponding Proto-West-Ugric protoword omits these consonants (and starts with a vowel). When the initial consonant of a Proto-Finno-Ugric protoword is *k*, then the corresponding Proto-West-Ugric protoword also starts with a *k*. This agrees with Róna-Tas’ observation [22] that the initial *š* omission process (*š* > *h* > *Ø*) must have been completed before the initial *kV* > *hV* process, where *V* is a back vowel, started.

Finally, note that the word *μέρμερος* can be explained by a reduplication of the Proto-Finno-Ugric root word *mär3*. We present more examples of regular sound changes in the journal version of this paper.

#### B. Implications for the Translation of the Minoan Inscriptions

The Minoan language was proposed to be Greek-like by Nagy [12], some other Indo-European language by Owens [14], or a Semitic language by Best [4] and by Gordon [8]. Unfortunately, these proposals and the translation attempts based on these ideas now can be proven to be misguided. However, Revesz [16-19] presented translations of over twenty Linear A and Cretan Hieroglyphic inscriptions under the assumption that Minoan is a Finno-Ugric language. These translations remain viable proposals in light of the regular sound changes between Minoan and the Finno-Ugric languages.

#### IV. CONCLUSIONS AND FUTURE WORK

The overall structure of the Uralic language family was already well-established by the mid-19<sup>th</sup> century, only a few decades after the first Finno-Ugric comparative linguistic publication by Sajnovics [23]. The picture remained essentially stable until Revesz [19] added the Minoan language to the Uralic language family based on a decipherment of the Minoan Linear A and Cretan Hieroglyph scripts. The above demonstration of Finno-Ugric and Minoan regular sound changes supports this classification.

Tables II and III enable the derivation of a more complete picture of the phonological history of the Uralic language family. We plan to build on this picture to develop an algorithm for the automatic reconstruction of Finno-Ugric protowords given present day forms and the EDG’s Pre-Greek words. Only the reverse direction was considered before when Bátori [1] implemented a computer program that could apply sound change rules and derive present day forms given a protoword.

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