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Contributions to the study of butterflies from Xinjiang - 5 the genus *Colias* Fabricius, 1807

(Lepidoptera: Pieridae)

by

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Abstract. A review is made on the *Colias* butterflies from Xinjiang, China. One new species and one new subspecies are described: *Colias alta **akazi*** **subspec. nov.** is described from Akazi Daban, West Kunlun Mountains; and *Colias **ling*** **spec. nov.** is described from Mazha Daban, West Kunlun Mountains. The following taxa are recorded as new to China: *Colias alta alta* Staudinger, 1886; *C. staudingeri pamira* Grum-Grshimailo, 1890; and *C. romanovi* Grum-Grshimailo, 1885. *Colias chrysotheme elena* Gorbunov, 1995 is confirmed to be a synonym of *Colias chrysotheme audre* Hemming, 1933. *C. cocandica kunjerabi* Verhulst, 2000 and *C. thisoa cryptochrysa* Yakovlev, 2006 are revalidated as good subspecies supported by molecular research. A new population of *C. arida arida* Alphéraky, 1889 is reported from Central Kunlun Mountains. A new population of *C. erschoffii* Alphéraky, 1881 was recorded from the Balluk Mountains. The little-known *C. wiskotti seres* Grum-Grshimailo, 1890 is reported.

Introduction. The pursuit of discovering new *Colias* butterflies has been a long-held dream for the author since he began collecting butterflies. Most species within this captivating group are highly selective about their habitats, presenting significant challenges to butterfly hunters. Alongside *Parnassius*, *Colias* has been a primary target during the author's three expeditions to Xinjiang. Remarkably, during his latest expedition to Xinjiang in 2024, a new species of *Colias* was unexpectedly discovered and is described herein. This discovery represents the third new Palaearctic *Colias* species described in the past 34 years, following previous findings by Verhulst (1991) and Karbalaye & Grieshuber (2019).

The third expedition to Xinjiang (for details on the first two expeditions, see Huang, 2023) was initially planned for early 2023 but was postponed until the spring of 2024. The author, accompanied by his friend Mr. Y.-H. Li from Nanning, explored several regions from June 1st to August 10th. These included the mountain ranges around Dalengdaban southwest of Korla, the Akqi area (encompassing the Kokshaal and Maidantag Mountain Ranges), the Wuqia area (including Irkeshtam, Uqitax, and Torugart near the Transalai, Alai, and At-Bashi Mountain Ranges), the Taxkorgan area (covering the Sarykol and Kunlun Mountains), and the Kunlun Moutains (including Mazha, Shahidulla, Sangzhu, and Cele). Notably, the author's previous "restriction" from exploring the Kunlun Mountains was lifted during this expedition.

Given that Grieshuber & Lamas (2007), Grieshuber et al. (2012) and Grieshuber (2014) have already provided comprehensive synonymic lists for all *Colias* taxa in the Palearctic region, there is no need to reiterate the extensive citations in this paper. Instead, the author has chosen to focus mainly on taxonomic changes and records relevant to Xinjiang in the citations. Regarding type material information, comprehensive discussions are available in Grieshuber et al. (2012). Consequently, this study only references the available illustrations of the type material in the "Type Material" section.

Abbreviations

BLXU:	Biological laboratory of Xinjiang University, Urumqi
BSNU:	Biological laboratory of Shanghai Normal University, Shanghai, P.R. China
CDL:	Collection of Liang Ding, Beijing
CHH:	Collection of Hao Huang, Qingdao
CLP:	Collection of Peng Li, Xi'an, Shaanxi
CXR:	Collection of Rui Xing, Urumqi
CQZY:	Collection of Zhi-Yuan Qi, Shanghai
ECSU:	Entomological Collection of Shihezi University
IPAEE:	Institute of Plant and Animal Ecology in Ekaterinburg
IRSN:	Institut Royal des Sciences Naturelles de Belgique, Brussels
IZMESK:	Institute of Zoology of the Ministry of Education and Science of the Republic of Kazakhstan
LSL:	Collection of the Linnean Society, London
MWNS:	Museum Wiesbaden, Naturwissenschaftliche Sammlung, Wiesbaden
NHML:	The Natural History Museum (London, UK)
SZMN:	Siberian Zoological Museum, Novosibirsk
TL:	Type locality
ZFMK:	Zoologische Forschungsinstitut und Museum Alexander Koenig (Bonn, Germany)
ZISP:	Zoological Institute, Russian Academy of Sciences (St.-Peterburg, Russia)
ZMHU:	Zoologisches Museum an der Humboldt-Universität zu Berlin (Germany)
ZMKU:	Zoological Museum, Kyiv National Shevchenko University (Kyiv, Ukraine)
ZSM:	Zoologische Staatssammlung (Münche, Germany)

A checklist of the *Colias* Fabricius taxa recorded from Xinjiang

1. *C. hyale hyale* (Linnaeus, 1758)
2a. *C. alta alta* Staudinger, 1886 - **new record**
2b. *C. alta **akazi*** Huang **subspec. nov.**
3. *C. erate erate* (Esper, [1805])
4. *C. tyche tyche* (Böber, 1812) - not confirmed
5. *C. grumi* Alphéraky, 1897

6. *C. tamerlana* Staudinger, 1897
7a. *C. cocandica maja* Grum-Grshimailo, 1891
7b. *C. cocandica pljushtchi* Verhulst, 2000
7c. *C. cocandica hinducucica* Tytler, 1926
7d. *C. cocandica kunjerabi* Verhulst, 1999
7e. *C. cocandica tatarica* O. Bang-Haas, 1915
8. *C. chrysotheme audre* Hemming, 1933
9a. *C. thisoa aeolides* Grum-Grshimailo, 1890
9b. *C. thisoa cryptochrysa* Yakovlev, 2006
10 *C. marcopolo* Grum-Grshimailo, 1888 - not figured
11. *C. eogene* C. Felder & R. Felder, 1865
12. *C. arida arida* Alphéraky, 1889
13. *C. wanda yangguifei* R.-X. Huang & Murayama, 1992
14. *C. **ling*** Huang **spec. nov.**
15. *C. wiskotti seres* Grum-Grshimailo, 1890
16a. *C. staudingeri staudingeri* Alphéraky, 1881
16b. *C. staudingeri pamira* Grum-Grshimailo, 1890 - **new record**
17. *C. romanovi* Grum-Grshimailo, 1885 - **new record**
18. *C. erschoffii* Alphéraky, 1881
19. *C. regia* Grum-Grshimailo, 1887 - not confirmed

Method. The ♂ genitalia structures in *Colias* species are typically highly conservative, often lacking reliable diagnostic characters (Grieshuber, 2014; Huang & Song, 2022). As a result, descriptions of ♂ genitalia are omitted in this study. Only the ♀ genitalia of *Colias hyale* and *C. erate* were examined to assess external differences in wing patterns between the two species.

The limited investigations into DNA sequences within this group (Wheat & Watt, 2008; Laiho & Stahls, 2013; Kir'yanov, 2021; Shapoval et al., 2023a; Shapoval et al., 2023b; Carvalho et al., 2024; Mo et al., 2025) have revealed the following insights. *Colias* is recognized as one of the most rapidly diversifying genera within the family Pieridae. Consequently, species of *Colias* exhibit relatively minimal divergence in both mitochondrial (mtDNA) and nuclear (nuDNA) sequences. Fragments of a few genes may lack sufficient phylogenetic informativeness to reconstruct an accurate species tree, and most species may not appear monophyletic in gene trees inferred from a limited number of loci. Recent foundational research on the phylogeny of *Colias* (Mo et al., 2025) demonstrates that nuDNA gene trees are entirely incongruent with the mtDNA gene tree (based on mitochondrial genomes). Moreover, nuDNA trees constructed from different numbers of nuclear gene loci exhibit significant topological differences among terminal taxa. These findings suggest that mitochondrial gene trees may be misleading for phylogenetic inference and species delimitation in fast-evolving taxa. Furthermore, analyses based on a small number of nuclear markers in such rapidly evolving groups may still fall short of revealing the true evolutionary relationships.

However, the author found that analyses based on limited fragments of mtDNA and nuDNA genes can be useful for elucidating relationships between closely related species or different subspecies, as well as for identifying specimens with subtle variations in wing patterns. Based on this approach, the following investigations were conducted in this study.

1) Two fragments of the mitochondrial COI gene, totaling 1497 base pairs (bp), were analyzed to infer the phylogenetic relationships between *C. hyale* (L.) and *C. alta* Staudinger, as well as between *C. erate* (Esper) and *C. poliographus* Motschulsky, 1861.
2) Two fragments of the mitochondrial COI gene (1421 bp) and two fragments of the nuclear EF1-alpha gene (1016 bp) were analyzed to explore the phylogenetic relationships among Chinese populations of *C. cocandica* Erschoff, 1874.
3) Two fragments of the mitochondrial COI gene (1421 bp) and two fragments of the nuclear EF1-alpha gene (1016 bp) were analyzed to explore the phylogenetic relationships among Chinese populations of *C. thisoa* Ménétriés, 1832.
4) Two fragments of the mitochondrial COI gene (1421 bp) were analyzed to assess the relationship between the northernmost and southernmost populations of *C. eogene* C. Felder & R. Felder.
5) Two fragments of the mitochondrial COI gene (1421 bp) were analyzed to identify a unique specimen of *C. staudingeri pamira* Grum-Grshimailo, representing its first record in China.
6) Two fragments of the mitochondrial COI gene (1421 bp), one fragment of the nuclear Rps5 gene (593 bp), and two fragments of the nuclear EF1-alpha gene (1016 bp) were analyzed to infer the phylogenetic relationships among *C. stoliczkana* Moore, 1878, *C. arida* Alphéraky, *C. wanda* Grum-Grshimailo, 1907, and the newly described species *C. ling* **spec. nov.**

DNA extractions were conducted by Beijing Tsingke Biotech Co., Ltd. (Beijing, China). The primers used are shown in Tables 1-2. Sequence matrices were aligned by Cluster W and edited manually using MEGA 11 (Tamura et al. 2021). Construction of the phylogenetic tree was performed by Maximum likelihood (ML) method using IQ-TREE as implemented in the web online server (Trifinopoulos et al. 2016), with branch support values evaluated based on 1000 replicates for SHaLRT and ultrafast bootstrap. The substitution model was set to "Auto" for the combined analysis of different genes. In addition to the material sequenced in this work, some *Colias* examples with their COI genes obtained from NCBI GenBank were also included in the molecular analysis.

Table 1. Forward and reverse primers names in this study

Gene	Forward primers	Reverse primers	References
COI part1 (barcode)	LCO1490	HCO2198	Folmer et al. 1994
COI part2	Jerry	Pat2	Simon et al. 1994, Yi et al. 2017
EF1-alpha part1	ef135	ef684	Kandul et al. 2004
EF1-alpha part2	ef51.9	efrcM4(r)	Cho et al. 1995
RPS5	RpS5-f	RpS5-r	Wahlberg & Wheat 2008

Table 2. Primers sequences in this study

Primers	Sequences	Annealing temperature
Jerry	CAACATTTATTTTGATTTTTT	48-52
Pat2	TCCATTA CATATAATCTGCCATATT	48-52
ef135	CAAATGYGGTGGTATYGACAAACG	55
ef684	TCCTTRCGCTCCACSTGCCAYCC	55
ef51.9	CAR GAC GTA TAC AAA ATC GG	50
efrcM4(r)	ACA GCV ACK GTY TGY CTC ATR TC	50
RpS5-f	ATG GCN GAR GAR AAY TGG AAY GA	55
RpS5-r	CGG TTR GAY TTR GCA ACA CG	55

Accession numbers. The mitochondrial COI gene sequences of the *Colias* specimens examined in this study have been deposited in GenBank under accession numbers PV397395-PV297442. Additionally, the RpS5 sequences are available under accession numbers PV423454-PV423463, and the EF1-alpha sequences under PV423464-PV423495.

All sequenced specimens are associated with voucher numbers, which are clearly indicated in dark red within the relevant figures.

List of collecting localities. For ease of reference, the specimens illustrated in this study are designated by simplified geographical names corresponding to their collection sites, with their respective longitude and latitude coordinates provided below.

Aertash: 37.98 N, 76.53 E
Akeqiaoke: 45.96 N, 82.88 E
Awusqi: 46.95 N, 85.14 E
Balluk, Tuoli: 45.61 N, 82.73 E
BC of Muztagh-ata: 38.29 N, 75.01 E
Dalengdaban: 42.45 N, 85.17 E
E Qinghe: 46.75 N, 90.87 E
Gongliu: 43.61 N, 81.84 E
Habahe: 48.19 N, 86.89 E
Horgos: 44.39 N, 80.38 E
Jinghe: 44.42 N, 83.13 E
N Hefeng: 47.05 N, 86.01 E
N Ruoqiang: 40.39 N, 88.07 E
Narat: 43.21 N, 84.33 E
NW Akqi: 40.87 N, 77.53 E
Qimantag Mts.: 37.74 N, 89.35 E
Road to Kanas: 48.33 N, 87.11 E
S Balluk: 45.51 N, 82.86 E
S Mazhadaban: 36.56 N, 77.00 E
S Yining: 43.50 N, 81.43 E
Sandaohaizi: 46.75 N, 90.87 E
SE Akqi: 40.67-40.78 N, 77.83-78.25 E
Takshken: 46.16 N, 90.95 E
Targabatai: 46.75 N, 83.17 E
Telmed Pass: 42.49 N, 83.41 E
Tuoli: 45.56 N, 82.57 E
Uqitax: 40.21 N, 74.58 E
Wakhan Corridor: 37.19 N, 75.32 E
Xinyuan: 43.59 N, 83.16 E
Zhaosu: 43.65 N, 80.46 E
33-44 km S Taxkorgan: 37.49-37.38 N, 75.35 E
Akazi-daban: 37.09 N, 76.96 E
Altun Shan: 38.37 N, 90.00 E
Baihaba: 48.62 N, 86.73 E
Bayinbuluke: 43.10 N, 84.58 E
Cele: 36.26 N, 81.06 E
Dushanzi: 44.15 N, 84.83 E
Gaijiake Pass: 37.03 N, 75.69 E
Guozigou: 44.46 N, 81.16 E
Hami: 43.19 N, 93.71 E
Irkeshtam: 39.67 N, 73.98 E
Maeryang Pass: 37.43 N, 75.64 E
N Mazhadaban: 36.57 N, 77.01 E
N Yining: 44.08 N, 81.50 E
No 76 Peak: 38.36 N, 89.60 E
Pishan: 37.22 N. 77.79 E
Qinghe: 46.49 N, 90,19 E
S Akqi: 40.67-40.78 N, 77.83-78.25 E
S Bogda: 43.72 N, 88.17 E
S Sangzhu: 36.90 N, 78.28 E
S Urumqi: 43.44 N, 87.67 E
Sangzhu-daban: 36.68 N, 78.25 E
SE Urumuqi: 43.70 N, 88.12 E
Tanbeixuefeng: 37.71 N, 90.67 E
Tekkes: 43.35 N, 81.83 E
Torugart: 40.48 N, 75.35 E
Tuoyun: 40.20 N, 75.32 E
W Wenquan: 44.91 N, 80.94 E
west bank of Karakul: 38.41 N, 75.01 E
Yiwu: 43.18 N, 94.36 E
189 km S of Cele: 36.07 N, 81.09 E
42 km S Taxkorgan: 37.39 N, 75.30 E

Taxonomic accounts

Colias hyale (Linnaeus, 1758) (figs. 2-3)

***Colias hyale hyale* (Linnaeus, 1758)**
"*Papilio (Danaus) Hyale*" Linnaeus, 1758: 469
"*C. Hyale* L. et hibr. *Sareptensis* Stgr." Alphéraky, 1881: 365-366, Kouldja & Tian-Chian.
TL: recte Europe, [northern] Africa
Type material: ♂ lectotype (LSL) was designated by Honey & Scoble (2001) and was figured by Grieshuber et al. (2012: pl. 1).

Material. 94 ♂♂, 72 ♀♀ (CHH), various localities in Xinjiang as shown in figs. 2-3, 740-3500 m, V-VIII.2019, 2022 & 2024, H. Huang & Y.-H. Li leg..
Remarks. Two generations were observed at several localities in Xinjiang, such as Xinyuan, Gongliu and Urumqi (= Urumuqi): the first in May and the second in June-August. While ♀♀ of this species are often morphologically similar to those of *C. erate* (Esper), they can be distinguished by specific wing pattern characteristics: the postdiscal black marking in space 1b on the forewing upper side are notably smaller and distinctly separated from the darker marginal border, neither forming an extensive loop through connection with the border nor merging completely with it. To validate these external morphological differences in ♀ wing patterns, we conducted a detailed examination of ♀ genitalia (fig. 33).
It is particularly noteworthy that several specimens were collected from high-altitude locations in the East Tianshan Mountains, specifically from Yiwu and Hami regions, at an elevation of 3500 meters.

Colias alta Staudinger, 1886 (figs. 1-2)

Grieshuber (2014) characterized this species as larger than *C. hyale* (L.), inhabiting higher altitudes, and being univoltine. However, our comparative morphological analysis of these two species in Xinjiang revealed no significant differences, including size variation. Furthermore, our discovery of a new population in the Kunlun Mountains demonstrates bivoltinism in this species. Current evidence suggests that these two taxa can only be reliably distinguished by their distributional ranges and molecular characteristics. Molecular analysis of two mitochondrial COI gene fragments (1497 bp) in this study (fig. 35) revealed minimal genetic divergence between *C. hyale* (L.) and *C. alta* Staudinger. Recent comprehensive research by Mo et al. (2025) utilizing 150 nuclear gene loci

(fig. 34, green section) indicates a close phylogenetic relationship between these species. The observed genetic distance between them corresponds to that typically found between populations or subspecies within a single species, and is substantially smaller than the divergence typically observed between distinct species. However, it should be noted that Mo et al. (2025) based their tree on limited sampling, examining only one specimen per species. Therefore, definitive taxonomic resolution requires additional specimens and expanded nuclear gene datasets.
Based on current evidence, we provisionally maintain *C. alta* Staudinger as a distinct species, while acknowledging the strong possibility that it may represent a subspecies of *C. hyale* (L.).

***Colias alta alta* Staudinger, 1886**
"Col. Hyale L. var. *Alta"* Staudinger, 1886: 200-201.
TL: Alai Gebirge. Grieshuber et al. (2012) interpreted the TL as Artscha-Basch, N Kara Kasuk Pass, SW Schahimardan, Alai, Kyrgyzstan.
Type material: 1 ♂, 1 ♀ syntypes (ZMHU) were figured by Tshikolovets et al. (2005b: pl 32). 3 ♂♂, 1 ♀ syntypes (ZMHU) were figured by Grieshuber et al. (2012: pl. 1).
Synonym. "*Colias worthyi*" Zhdanko, 2012: 33-34, fig. 1 for ♂ genitalia (synonymized by Grieshuber, 2014)
TL: Kyrgyzstan, Baidulu Range, Ottuk Valley.
Type material: None was figured. The type specimens are deposited in ZISP, IZMESK and private collection of S. Toropov.
Material. 7 ♂♂, 3 ♀♀ (CHH), Uqitax, Wuqia, Xinjiang, 3100-3200 m, 2.VIII.2022, H. Huang leg.; 1 ♂ (CHH), Uqitax, 3200 m, 26.VI.2024, H. Huang leg.; 1 ♂ (CHH), Uqitax, 3200 m, 4.VII.2024, H. Huang leg.
Remarks. Field observations conducted by the author in early June at Uqitax did not yield any specimens of this species. The flight period of this population extends from late June through early-August, suggesting a univoltine life cycle.

***Colias alta a k a z i* subspec. nov.** (fig. 1)
Holotype ♂: China, Xinjiang, Yecheng, north of Akazi Daban (=Kudi Daban), 2945 m, 11.VI.2024, H. Huang leg., deposited in BSNU.
Paratypes: Xinjiang: 3 ♂♂, 2 ♀♀ (CHH), three localities on north of Akazi Daban, 2590-2945 m, 11.VI.2024, H. Huang leg.; 2 ♂♂ (CHH), same locality as holotype, 13.VIII.2024, H. Huang leg.
Etymology. This new subspecies is named after its type locality, Akazi Daban (also known as Kudi Daban).
Diagnosis. The new subspecies can be distinguished from the nominotypical subspecies by the following combination of characteristics:
1) The underside hindwing ground colour is darker and more extensively dusted with black scales in both sexes, particularly evident in the submarginal area.
2) The upper side hindwing ground colour in ♀♀ is frequently darker.
Field observations. This new subspecies exhibits two generations annually, with the first generation emerging in early June and the second in late July to mid-August. The author conducted field visits to the biotopes twice in July, specifically from 5-7 July and 18-19 July, but did not encounter this butterfly. This suggests that the emergence of this *Colias* is not continuous from June to August but is interrupted in July. The biotopes span an elevation range of 2500-3000 m, which is notably lower than that of the nominotypical subspecies. Additionally, the author explored the intermediate mountain ranges (Sarykol and Kunlun Mountains) between the type locality and the Wuqia area multiple times but did not find this species.
Discussion. Analysis of two fragments of the mitochondrial COI gene (1497 base pairs) revealed no differences between *C. alta akazi* **subspec. nov.** and *C. alta alta* Staudinger. However, the subspecific division is justified based on significant differences in the hindwing underside ground colour and the considerable geographical isolation between the known populations. Further studies involving additional nuclear DNA (nuDNA) genes are recommended to provide more comprehensive insights.
Distribution. Kunlun Mts. (area around Akazi Daban only).

***Colias erate* (Esper, [1805])** (fig.. 3-5)
The treatment proposed by Grieshuber (2014), which places *C. poliographus* Mots., 1861 and *C. erate* (Esper) as sister species, is contradicted by recent molecular research conducted by Mo et al. (2025). Utilizing 150 nuclear gene loci (fig. 34, yellow section), Mo et al. (2025) analyzed four specimens (two of *C. erate* (Esper) from Xinjiang and two of *C. poliographus* Mots. from Yunnan) and found that the two *C. erate* (Esper) specimens did not form a monophyletic clade. To maintain the monophyly of *C. erate* (Esper), it is necessary to include *C. erate poliographus* Mots. **stat. rev.** as conspecific with *C. erate* (Esper).
Molecular analysis of two mitochondrial COI gene fragments (1497 bp) in this study (fig. 35, green section) reveals the following:
1) Populations from Xinjiang, except those from the Ruoqiang Desert, are genetically indistinguishable from those of Europe and Central Asia.
2) The population from the Ruoqiang Desert (eastern part of the Taklimakan Desert) is genetically closer to populations from Northeast Asia, which are typical *C. erate poliographus* Mots.
3) The population from Jilong, southern Tibet, which resembles *C. erate erate* (Esper), is genetically closer to typical *C. erate poliographus* Mots. from Northeast Asia than to *C. erate erate* (Esper) from Xinjiang.
4) The population from northwestern Gansu (applicable to *C. erate amdensis* Bollow, 1930) appears to be genetically distinct from both *C. erate erate* (Esper) and *C. erate poliographus* Mots.
Since this study is based on very short fragments of the mitochondrial COI gene, the results do not hold substantial definitive significance but rather offer only limited heuristic value. Nevertheless, they suggest that the samples from the Ruoqiang Desert and those from Jilong in southern Tibet are worthy of further in-depth investigation. Similarly, materials from the mountainous regions along the western periphery of the Qinghai-Tibet Plateau in China also merit more comprehensive study in the future. Unfortunately, due to financial constraints, the author was unable to analyze additional specimens or include more gene markers in this study. It is not the primary aim of this paper to resolve the systematics of *C. erate* (Esper), and the author welcomes future collaborations on this topic.

***Colias erate erate* (Esper, [1805])**
"*Pap. Dan. cnndidus, Erate*" Esper, [1805]: 13-14, pl. 119, fig. 3.
"*C. Erate* Esp.; ab. f *Pallidaa* Stgr.; ab. *Chrysodona* Kind." Alphéraky, 1881: 367-368, Kouldja & Tian-Chian.

TL: Sarepta. Grieshuber et al. (2012) interpreted the TL as Krasnoarmejsk, Volgogradskaya Region, S Russia.
Type material: ♂ holotype (MWNS) was figured by Grieshuber et al. (2012: pl. 2).
Material. 138 ♂♂, 86 ♀♀ (CHH), various localities in Xinjiang as shown in figs. 3-5, 740-3500 m, V-VIII.2019, 2022 & 2024, H. Huang & Y.-H. Li leg..
Remarks. Rare orange forms in both sexes were observed in populations from Horgos, the Balluk Mountains, and the southeastern Altai. The unique ♂ specimen collected from the Ruoqiang Desert (fig. 4-ER2) is tentatively assigned to this subspecies, pending further research on additional material. This specimen differs from ♂♂ from all other known localities in Xinjiang by exhibiting a whiter ground colour on the upper side of both wings (resembling *C. hyale* (L.)), a narrower and interrupted marginal band on the hindwing upper side, and the complete absence of submarginal markings on the hindwing upper side. Genetically, it is closely related to *C. erate poliographus* Mots. Unfortunately, only a single ♂ specimen has been collected to date.

***Colias tyche tyche* (Böber, 1812)**

"*Colias tyche* Boeber" R. X. Huang et al., 2000: 25, record from Altai-shan, pl. XI, fig. 2 for "♀" (actually ♂- copied from Lukhtanov & Lukhtanov, 1994).
"*Colias tyche* (Böber, 1812)... ssp. *tyche*" Grieshuber, 2014: 22, record from NW China (Altai), giving no reference or figure.

Remarks. The record by R. X. Huang et al. (2000) is a fabricated entry intended to enrich their book, as it provides no collecting data or specimen figure. They published an image copied from Lukhtanov & Lukhtanov (1994) and incorrectly identified the ♂ specimen in the figure as ♀. Grieshuber's (2014) record also lacks any reference or specimen figure, necessitating further verification. To date, no specimen of this species has been collected by any Chinese collectors known to the author, although it is possible that the species occurs in Xinjiang.

***Colias grumi* Alphéraky, 1897** (fig.6)

"Colias Cocandica Ersch. var. *Grumi* Alph. nova." Alphéraky, 1897: 233-234
TL: Humboldt... Nan Chan. Grieshuber et al. (2012) interpreted the TL as ca. 21 km W Yanchiwan, Danghe Nanshan, border area between Gansu and Qinghai.
Type material: The ♂ lectotype (ZISP) was designated and illustrated alongside a ♀ paralectotype by Grieshuber & Churkin (2003). Additionally, the ♂ lectotype and seven paralectotypes (comprising both♂♂ and ♀♀, housed at ZISP, NHML, and ZMKU) were figured by Grieshuber et al. (2012).
Synonym. "*C. cocandica*, Ersch. var. *evanescens*" Verity, 1908: pl. XLII, fig. 16 (synonymized by Grieshuber et al. (2012))
TL: region du Lob-Nor. Grieshuber et al. (2012) interpreted the TL as northern slopes of the Altun Shan, border area of Xinjiang, Gansu and Qinghai.
Type material: ♀ holotype (ZMKU) was figured by Verity (1908), Tshikolovets & Kostjuk (1994), Verhulst (2000) and Grieshuber et al. (2012).
Synonym. "*Colias grumi burchana* nov. ssp." Mracek & Schulte, 1991: 163-165, fig.s 1-2 (synonymized by Grieshuber et al. (2012))
TL: Qinghai, Kunlun-Shan, Burchan-Buddha, West Big Desert (= Xidatan).
Type material: Male holotype (private collection of Hara, Sagamihara) was illustrated in original description alongside a ♀ paratype (coll. Hara). Two pairs of paratypes (coll. Rose, now in ZFMK) were illustrated by Grieshuber et al. (2012).
Synonym. "*Colias alpherakyi aljinshana* ssp. nov." R. X. Huang & Murayama, 1992: 5, pl. 2, fig. 11 (synonymized by Grieshuber et al., 2012).
TL: Aljinshan, 4300 m, high cold desert mountain. Huang & Song (2022) interpreted the TL as the Qimantag Shan, no north of Tufangzi (37.3224N, 90.3562E).
Type material: Only ♂ holotype and 2 ♂♂ paratypes are known (Huang & Song, 2022); ♀ unknown. ♂ holotype (BLXU) was illustrated in original description; 1 ♂ paratype (BLXU) was illustrated by Huang & Song (2022).
Material. 1 ♂, 2 ♀♀ (CHH), Altun Shan, Xinjiang, ca. 38.3740 N, 90.0027 E, 3830 m, 25.VII.2021, R. Xing leg.; 1 ♂ (CHH), Duxuefeng Peak, Qimantag Mts., 37.5092 N, 90.3186 E, 4150 m, 28.VII.2024, R. Xing leg.
Remarks. The unique ♂ specimen from Qimantag (TL of *aljinshana*) exhibits a large pale spot in space 2 of the marginal band, along with a broad pale band near the costa, consistent with the type specimens of *C. alpherakyi aljinshana* R. X. Huang & Murayama. However, similar forms are occasionally observed in other populations from Qinghai as well.

***Colias tamerlana* Staudinger, 1897** (fi.. 6-7)

TL: nördlich von Chamyl = Hami
Material. 7 ♂♂, 3 ♀♀ (CHH), Yiwu, Hami, E Xinjiang, 3300-3600 m, 7.VII.2022, H. Huang leg.; 10 ♂♂, 9 ♀♀ (CHH), Sandaohaizi, E Qinghe, SE Altai, Xinjiang, 2570-2700 m, 17.VI.2022, H. Huang leg.
Remarks. Shapoval et al. (2023b) concluded based on DNA analysis that all subspecific taxa recognized by Grieshuber (2014) are synonymous, suggesting that the species lacks subspecific division. A comprehensive synonymic list for this species can be found in Grieshuber (2014) and Shapoval et al. (2023b).
In China, the recently discovered population from Sandaohaizi, Qinghe, does not exhibit consistent external differences compared to the topotypic population from Hami (TL).

***Colias cocandica* Erschoff, 1874** (fig. 8-15)

Two fragments of the mitochondrial COI gene (1421 bp) and two fragments of the nuclear EF1-alpha gene (1016 bp) were analyzed to investigate the phylogenetic relationships among Chinese populations of *C. cocandica* Erschoff, 1874. The results revealed five well-supported clades, each corresponding to a described subspecies (fig. 36). Three western subspecies outside China (listed as the first three entries below) were excluded from the analysis due to a lack of material. Data available in GenBank for this species were also excluded, as only COI barcode sequences were applicable, which are too short to yield meaningful results.

***Colias cocandica cocandica* Erschoff, 1874**

TL: interpreted by Grieshuber et al. (2012) as Matcha Mts. between Dzhiptyk Pass and the Shurovski glacier, Turkestansky Range, SW Kyrgyzstan

Synonym. "*Colias cocandica mraceki* ssp. nova" Verhulst, 1999: 268-269, pl., figs.7-8, 15-16, 19 (nec 20). Synonymized by Grieshuber et al. (2012).
Remarks. The synonymy of *Colias cocandica mraceki* Verhulst with this subspecies requires confirmation through future molecular studies.
Distribution. SW Kyrgyzstan, NW Tajikistan, SE Uzbekistan.

***Colias cocandica culminicola* Kotzsch, 1936**
TL: high mountains of the Andarab area, Baghlan, northern Afghanistan.
Distribution. Afghanistan (Hindukush Mts. exept the eastern end, Kohibaba Mts.), Tajikistan (SW & SC Pamir).

***Colias cocandica tanyusha* Churkin & Dovgailo, 2014**
TL: S Dzhungaria, Toksanbai Range, Uitas Mt. (south slope), upper stream of B. Kybyl River, 3000-3250 m.
Distribution. Kazakhstan (Uitas Mts.).

***Colias cocandica maja* Grum-Grshimailo, 1891**
"*Colias Cocandica* var. *Maja*" Grum-Grshimailo, 1891: 447; Grieshuber & Churkin, 2003: 257, lectotype designation, cpl. 16, figs. 3-4 for ♂ lectotype and ♀ paralectotype.
TL: north Boro-Choro. Grieshuber et al. (2012) interpreted the TL as 40 km SE Jinghe.
Type material: ♂ lectotype (ZISP) was designated and illustrated by Grieshuber & Churkin (2003) alongside a ♀ paralectotype (ZISP); 1 further ♀ paralectotype (NHML) was illustrated by Grieshuber et al. (2012) and 1 further ♂ paralectotype (ZISP) was illustrated by Grieshuber (2014). The photos of the lectotype, 7 ♂♂ paralectotypes and 2 ♀♀ paralectotypes are available on the internet, uploaded by Grieshuber.
Material. 24 ♂♂, 9 ♀♀ (CHH, CLP), S Akqi, pass of Maidantag Mts., 3400-3600 m, 12.VII.2019, H. Huang & P. Li leg.; 1 ♂ (CHH), Telmed Pass, Halke Shan (Halyktau Mt. Range), N of Kuqa, 3400 m, 26.VII.2019, P. Li leg.; 1 ♂ (CHH), Telmed Pass, 3400 m, 24.VI.2024, L. Ding leg.; 3 ♂♂ (CHH), Telmed Pass, 2900 m, 10.VIII.2024, H. Huang leg.; 6 ♂♂, 2 ♀♀ (CHH), Dalengdaban, W Korla, 3370 m, 4.VII.2022, H. Huang leg.; 1 ♂ (CXR), Aiken-daban, on road from Yining to Korla, 3200 m, 23.VI.2022, R. Xing leg.; 1 ♂ (CXR), Xiata, S of Zhaosu, Halke Shan, 3500 m, 24.VI.2008, R. Xing leg.
Remarks. In addition to the type material, Grieshuber et al. (2012) documented the collection of new specimens from the Borohoro Shan, approximately 100-110 km southeast of Urumqi, and the Halke Shan, although specific details were not provided. Churkin & Dovgailo (2014) further noted that additional specimens were collected by S. Murzin from North Borohoro and by S. Saluk from the Chinese Tian Shan (also referred to as Halke Shan). The author of this study collected some specimens from three distinct locations: one in the Maidantag Mountain Range and the other two from different sites within the Halke Shan (Telmed Pass and Dalengdaban near Korla). His friend, Mr. R. Xing, collected this subspecies from two additional localities: one at Aiken-daban on the southern slope of the Eren Habirga Mts., and the other at Xiata, near the westernmost part of the Halke Mts. Grieshuber et al. (2012) examined some older specimens labeled as originating from Kuruk-Tagh and expressed doubts about their provenance; the author concurs with this assessment and suspects that these specimens were likely collected from the eastern end of Halke Shan, located immediately to the west of Kuruk-Tagh.
The population from the Maidantag Mountain Range exhibits minimal genetic divergence from those in the Halke Shan, which Grieshuber et al. (2012) and Churkin & Dovgailo (2014) classified as *C. cocandica maja* Grum-Grshimailo. However, topotypic specimens, which the author did not collect, were not included in the molecular analysis. Therefore, further molecular studies on topotypic specimens of *C. c. maja* Grum-Grshimailo are essential to clarify their taxonomic status and relationships.
It is noteworthy that all known ♀ type specimens of *C. c. maja* Grum-Grshimailo exhibit a pale yellowish ground colour on the upper side of the wings, and no white form in ♀♀ has been documented from Borohoro, to the author's knowledge. Similarly, the southern Dzhungarian *C. c. tanyusha* Churkin & Dovgailo also displays a very low proportion of the white form in ♀♀ (less than 20%). In contrast, all known ♀ specimens of *C. c. maja* Grum-Grshimailo from the Halke Shan consistently exhibit a white ground colour. Whether *C. c. tanyusha* Churkin & Dovgailo and *C. c. maja* Grum-Grshimailo are genetically closely related, and whether the specimens from the Halke Shan truly belong to *C. c. maja* Grum-Grshimailo, remain unresolved questions that warrant further investigation.

***Colias cocandica pljushtchi* Verhulst, 2000**
"Colias cocandica pljushtchi ssp. nov." Verhulst, 2000: 144-145.
TL: Dolon Pass, Baidulla Mts., Kyrgyzstan.
Type material: 11 ♂♂, 5 ♀♀ paratypes (coll. Verhulst) were illustrated by Verhulst (2001). 2 ♂♂ paratypes (coll. Grieshuber) were illustrated by Grieshuber et al. (2012).
Material. 4 ♀♀ (CHH), Irkeshtam, Wuqia, 3400-3500 m, 15-19.VII.2019, H. Huang leg.; 1 ♀ (CHH), Uqitax, Wuqia, 3200-3300 m, 26.VI.2024, H. Huang leg.; 8 ♂♂, 9 ♀♀ (CHH), Torugart, Wuqia, 3500-3700 m, 1.VIII.2022, H. Huang leg.; 1 ♂ (CHH), Torugart, 3500 m, 2.VII.2024, H. Huang leg.; 27 ♂♂, 25 ♀♀ (CHH), NW Akqi, Kokshaal Mt. Range, 3500-3950 m, 29.VI. & 9-10.VII.2024, H. Huang & Y.-H. Li leg.
Remarks. The population of this subspecies from NW Akqi on the southern slope of the Kokshaal Mts. is clearly distinct from the population of *C. c. maja* Grum-Grshimailo found in the Maidantag Mts., based on both external morphological characteristics and DNA sequence data. The Akqi basin, situated between these two mountain ranges, appears to play a significant zoogeographic role in separating the high-altitude butterfly faunas on either side. While a small proportion of ♀♀ from NW Akqi are morphologically indistinguishable from those of the Maidantag Mts., the ♂♂ are consistently distinguishable by their smaller size and darker colouration on the upper side of the wings.
The population from the Kokshaal Mts. is likely attributable to *C. c. pljushtchi* Verhulst, as the Kokshaal range is geographically proximate to the Baidulla Mts. (TL of *pljushtchi*) and shares zoogeographic continuity with the latter. However, populations from Torugart and Uqitax (near the junction of the Fergana and Alai Mountains) exhibit genetic divergence from the Kokshaal population, despite showing no discernible differences in wing morphology.
An intriguing question for future research is whether the populations from Wuqia (including Torugart, Uqitax, and Irkeshtam) are genetically more closely related to *C. c. cocandica* Erschoff than to *C. c. pljushtchi* Verhulst. Currently, these populations are provisionally classified under *C. c. pljushtchi* Verhulst due to their pale phenotypic appearance.

***Colias cocandica hinducucica* Tytler, 1926**

"C hinducucica" Tytler, 1926: 253; Grieshuber et al. (2012): 119, nomenclature discussion, lectotype designation, pl. 13, figs. 9-10 for ♂ lectotype and ♀ paralectotype.

"*Colias cocandica* [race] *hinducucica* Bollow, 1930" Grieshuber & Lamas (2007): 139, incorrect name (corrected by Grieshuber et al., 2012).

TL: Hindou-Kouch and Pamir merid. Grieshuber et al. (2012) interpreted TL as Beik Pass.

Type material: ♂ lectotype (NHML, from Beik Pass) was designed and illustrated by Grieshuber et al. (2012) alongside a ♀ paralectotype (NHML).

Material. 4 ♂♂, 6 ♀♀ (CHH), 42 km south of Taxkorgan, east slope of Sarykol Mts., 4300-4700 m, 29.VII.2024, H. Huang & Y.-H. Li leg.; 4 ♂♂, 3 ♀♀ (CQZY), same data as foregoing specimens but Z.-Y. Qi leg.; 1 ♂, 1 ♀ (CHH), east slope of Sarykol Mts. just on west of Karakul lake, 4400-4500 m, 3.VIII.2024, H. Huang leg.; 1 ♂ (CHH), base camp of Mustag-Ata, 4400 m, 1.VIII.2024, H. Huang leg.

Remarks. The primary locality where the author collected this subspecies is directly connected to Beik Pass (TL) and is not interrupted by any deep or wide valleys. All collected specimens align with the type material in terms of wing-pattern, characterized by the presence of relatively large and continuous pale submarginal spots on both sides of the hindwing.

Grieshuber (2014) speculated that this subspecies might potentially be synonymous with *C. c. tatarica* Bang-Haas from the Chotan region of the western Kunlun Mountains. However, molecular analysis conducted in this study reveals that both *C. c. hinducucica* Tytler and *C. c. kunjerabi* Verhulst are genetically distinct from *C. c. tatarica* Bang-Haas.

Grieshuber & Lamas (2007) previously regarded *C. c. kunjerabi* Verhulst from the nearby Kunjerab Pass (located no more than 60 km from Beik Pass) as a synonym of *C. c. hinducucica* Tytler. This viewpoint was followed by Grieshuber et al. (2012) and Grieshuber (2014). Initially, the author adopted this viewpoint. However, subsequent molecular analysis of these two subspecies indicates that the populations from the Beik area and the Kunjerab area are genetically distinct. These two areas are separated by a deep and wide valley extending from Taxkorgan. In terms of wing-pattern, *C. c. hinducucica* Tytler appears to be indistinguishable from *C. c. kunjerabi* Verhulst. A similar case is observed in *C. c. tatarica* Bang-Haas, which is nearly indistinguishable in wing characters but exhibits distinct DNA sequence data.

***Colias cocandica kunjerabi* Verhulst, 1999 stat. rev.**

"Colias cocandica kunjerabi, ssp. nova." Verhulst, 1999: 267-268, pl. figs. 1-5.

"Colias cocandica kunjerabi Verhulst, 1999" Grieshuber & Lamas, 2007: 140, synonymy for *Colias cocandica hinducucica* Bollow, 1930.

"Colias cocandica hinducucica Tytler, 1926" Grieshuber, 2014: 38, figs. for 2 ♂♂, 1 ♀ from Kunjerab Pass.

"Colias cocandica cocandica Erschoff, 1874" Tshikolovets & Pages, 2016: 115-116, pl. 17, figs. 17-18, 20-21 for ♂♂ and ♀♀ from Kunjerab Pass.

TL: Kunjerab Pass.

Type material: The ♂ holotype (IRSN) was illustrated by Verhulst (1999), accompanied by two pairs of paratypes. Additional paratypes were subsequently depicted by Verhulst (2001).

Material. 4 ♂♂, 3 ♀♀ (CHH), Maeryang Pass, 4400 m, 15.VII.2024, H. Huang leg.; 2 ♀♀ (CHH), Gaijiake Pass, NE of Kunjerab Pass, 4400 m, 27.VII.2023, R. Xing leg.

Remarks. As mentioned under *C. c. hinducucica* Tytler, this subspecies is primarily recognized based on DNA sequence data. A potential diagnostic feature in wing-pattern is that a significant percentage of *C. c. kunjerabi* Verhulst specimens exhibit a more pronounced contrast between the black postdiscal area and the pale antediscal area on the upper side of the hindwing compared to *C. c. hinducucica* Tytler.

However, *C. c. kunjerabi* Verhulst appears to be entirely indistinguishable from *C. c. tatarica* Bang-Haas in terms of wing-pattern, despite the two subspecies being genetically distinct based on DNA sequence data.

***Colias cocandica tatarica* O. Bang-Haas, 1915**

"Colias cocandica tatarica O. B.-H. n. var."O. Bang-Haas, 1915: 98-99; Grieshuber & Churkin, 2003: 260, lectotype designation, cpl. 15, figs. 7-9 for lectotype and paralectotypes.

TL: Grieshuber et al. (2012) interpreted TL as SW Chotan, NW Kunlun Range.

Type material: Male lectotype (ZSM) was designated and illustrated by Grieshuber & Churkin (2003), accompanied by a pair of paralectotypes. Additional paralectotypes were later depicted by Grieshuber et al. (2012) and Grieshuber (2014). Photographs of the lectotype, along with more than 30 ♂♂ paralectotypes and over 10 ♀♀ paralectotypes (housed at ZSM, ZISP, and ZMHU), have been made available online by Grieshuber.

Material. 10 ♂♂, 1 ♀ (CHH), north slope of Sangzhu daban, W Kunlun Mts., 4300 m, 26.VII.2024, H. Huang leg.

Remarks. According to Grieshuber et al. (2012), the TL may correspond to one of the three ancient routes connecting Chotan (Hotan) to Shahidulla (Saitula). These routes include: 1) The easternmost Kangxiwa Ancient Road, which follows the Karakash River and crosses the Kurat Pass and Hindutash Pass (also known as Yinditashi Daban); 2) The median Sangzhu (Sanju) Pass Route, traversing the Sangzhu Daban; 3) The westernmost Kiliyang (Kiliang) Pass Route, crossing the Kiliyang Daban. Grieshuber et al. (2012) tentatively proposed the first route (Kangxiwa Ancient Road) as the TL, though conclusive evidence was lacking. Therefore, we consider the entire area encompassing these three routes as the potential range around the TL.

The specimens examined in this study represent the first additional material collected beyond the original type series. If the TL designation by Grieshuber et al. (2012) is accurate, the new collection site likely lies within 100 km west of the TL. These specimens align morphologically with the type material in wing characteristics and are indistinguishable from *C. c. kunjerabi* Verhulst found further west. Nevertheless, their subspecific classification is strongly supported by DNA sequence data.

***Colias chrysotheme audre* Hemming, 1933** (fig. 16)

"Colias Chrysotheme var. *Sibirica"* Grum-Grshimailo, 1893: 38 ; Grieshuber et al., 2012: 201, lectotype designation, pl. 16, fig. 10 for ♀ lectotype (NHML), fig. 9 & 11 for ♂ & ♀ paralectotypes (Preoccupied name: junior homonym of *Colias sibirica* Lederer, 1853)

"*Colias chrysotheme audre* nom. nov. pro *Colias chrysotheme* Esp. var. *sibirica* Gr.-Gr." Hemming, 1933: 278, replacement name; Tshikolovets, Yakovlev & Balint, 2009: 72, synonymy for *Colias chrysotheme chrysotheme* (Esper, [1781]), pl. 9, figs. 16 & 21.

"*Colias chrysotheme yangguifei*" R. X. Huang & Murayama, 1992: 4-5, partim on ♀ paratypes, 2-fig. 7 for ♀ paratype. Misidentification.
"*Colias chrysotheme chrysotheme* (Esper, [1781])" Tshikolovets, Yakovlev & Kosterin, 2009: 91, partim, pl. 12, figs. 4-5 for syntypes (now paralectotypes) of *sibirica*, figs. 3 & 6; Tshikolovets, Yakovlev & Balint, 2009: 72-73, records for Mongolia, pl. 9, figs. 16 & 21.
"*Colias thisoa aeolides*" Tshikolovets, Yakovlev & Balint, 2009: pl. 9, figs. 6 & 9. Misidentification.
TL: Krasnojarsk. Grieshuber et al. (2012) interpreted TL as southern parts of Buryatia and Chitinskaya Region, Siberia, Russia.
Type material: ♀ lectotype (NHML) was designated and figured by Grieshuber et al. (2012) alongside a pair of paralectotypes (ZISP). Another pair of paralectotypes (ZMKU) were illustrated by Tshikolovets, Yakovlev & Kosterin (2009).
Synonym. "*Colias chrysotheme elena* P. Gorbunov, sbsp. n." Gorbunov, in Korshunov & Gorbunov, 1995: 67-68, fig. 102; Tshikolovets, Yakovlev & Kosterin, 2009: 92-93, pl. 12, figs. 7-8 for paratypes, figs. 9-12; Tshikolovets, Yakovlev & Balint, 2009: 73, pl. 9, figs. 13-15, 17-18; Grieshuber et al., 2012: pl. 16, partim on figs. 7-8. (Synonymized by Verhulst, 2001).
TL: Grieshuber et al. (2012) interpreted TL as vicinity of Aktash, SE Altai.
Type material: ♂ holotype (IPAEE) and 1 ♀ paratype were figured in hand-drawn monochrome in original description. A pair of paratypes (SZMN) were illustrated by Tshikolovets, Yakovlev & Kosterin (2009).
Material. 1 ♂ (CHH), Sandaohaizi, Qinghe, SE Altai, Xinjiang, 2400 m, 15.VII.2022, H. Huang leg.; 1 ♂, 2 ♀♀ (CXR), Sandaohaizi, 2500 m, 29-30.VI.2017, R. Xing leg.
Remarks. Tshikolovets et al. (2009a, b) incorrectly treated *Colias chrysotheme audre* Hemming, 1933 as a synonym of *Colias chrysotheme chrysotheme* (Esper, [1781]). Grieshuber et al. (2012) and Grieshuber (2014) clarified the diagnostic characters and ranges of these two subspecies, and their interpretation is followed in this work.
The primary question revolves around the subspecific identity of *C. chrysotheme elena* Gorbunov. Tshikolovets, Yakovlev & Kosterin (2009) maintained *C. c. elena* Gorbunov as distinct from *C. c. audre* Hemming and illustrated type specimens for both taxa. However, the wing-pattern differences between these type specimens are insufficient to support their conclusion. Similarly, Tshikolovets, Yakovlev & Balint (2009) also treated *C. c. elena* Gorbunov as distinct from *C. c. audre* Hemming, but their illustrated specimens do not substantiate this view, as the ♀♀ of *C. c. elena* Gorbunov identified by them are indistinguishable from those of *C. c. audre* Hemming. Verhulst (2001), on the other hand, considered these two taxa to be the same subspecies.
Later, Grieshuber et al. (2012) and Grieshuber (2014) treated *C. c. elena* Gorbunov as distinct from *C. c. audre* Hemming, and their illustrations of ♀ specimens provide stronger support for this distinction. However, a discrepancy arises because the ♀ specimens identified by Grieshuber are darker and do not match the paratype ♀ perfectly illustrated by Tshikolovets, Yakovlev & Kosterin (2009: pl. 12, fig. 8). Such dark ♀♀ were also collected by the author and his colleague, Mr. R. Xing, from the Chinese part of the southeastern Altai (Sandaohaizi). The author agrees with Grieshuber that a dark form of ♀ exists in the Altai region, which is easily distinguishable from the normal ♀♀ of *C. c. audre* Hemming. Surprisingly, molecular analysis of such dark ♀♀ revealed that they actually belong to *C. thisoa* Ménétriés, 1832, rather than *C. chrysotheme* (Esper).
The two ♀♀ identified by Grieshuber as *C. c. elena* Gorbunov (reproduced herein as fig. 16-O & N) closely match the specimen used for molecular analysis in this study (fig. 16-K). These ♀♀ (fig. 16-K, fig. 18-left top) were collected alongside normal ♀♀ of *C. c. audre* Hemming (fig. 16-F & G). It is evident that *C. c. elena* Gorbunov cannot be maintained as distinct from the normal form of ♀, which is nearly inseparable from *C. c. audre* Hemming from Siberia. Useful diagnostic characters to distinguish the similarly appearing ♀♀ of the two species include the following: the orange ground colour on the forewing upper side and the brown ground colour on the hindwing upper side are very uniform in *C. thisoa* Ménétriés but not in *C. chrysotheme* (Esper); the black inner edges of the hindwing upper side submarginal spots are always well-marked in *C. thisoa* Ménétriés but are only rarely seen in *C. chrysotheme* (Esper) (fig. 16-I).
It is noteworthy that the ♀ specimen from Aktash in the Grieshuber collection, illustrated by Grieshuber et al. (2012: pl. 16, fig. 8; reproduced here as fig. 16-I), belongs to *Colias chrysotheme* (Esper) and represents a dark form of *C. c. elena* Gorbunov. However, this dark form also occurs in Terelji, eastern Mongolia (the widely recognized range of *C. c. audre* Hemming), as Yazaki (2000: 45, figs. 1-4) documented and figured such dark specimen alongside typical *C. c. audre* Hemming individuals.
Molecular analysis (fig. 36) demonstrates that the genetic divergence between the *C. chrysotheme* (Esper) specimen collected from the southeastern Altai and the one from northeastern China is remarkably small. In conclusion, *C. c. elena* Gorbunov should be treated as a junior synonym of *C. c. audre* Hemming, based on the ♂ and ♀ paratypes illustrated by Tshikolovets, Yakovlev & Kosterin (2009). Although the ♂ holotype of *C. c. elena* Gorbunov has never been illustrated in high-quality photographs, it can be inferred that it is unlikely to belong to *C. thisoa* Ménétriés. This is because Aktash and Ongudai, the TL of *C. c. elena* Gorbunov, are located very close to the TL of *C. thisoa nikolaevi* Korshunov, 1998, where only the normal forms of *C. thisoa aeolides* Grum-Grshimailo are known. This geographical proximity and the absence of atypical forms in the region strongly suggest that the holotype of *C. c. elena* Gorbunov does not represent *C. thisoa* Ménétriés.
The first record of this taxon from Xinjiang might be the 2 ♀♀ paratypes of *Colias chrysotheme yangguifei* R. X. Huang & Murayama, 1992 (now treated as *C. wanda yangguifei* Huang & Murayama), which were incorrectly labeled as from Altun Shan and wrongly associated with the ♂ type specimens of *C. wanda yangguifei* Huang & Murayama. One of these 2 ♀♀ waere located by Dr. Xin Zhang (Urumqi) at Xinjiang University and were colour-illustrated by Huang & Song (2022), though without collection data labels. The actual locality of these ♀♀ may be somewhere in the Chinese Altai.

Colias thisoa Ménétriés, 1832 (fig. 16-18)

Five subspecies were recognized by Grieshuber (2014), three of which are known from Xinjiang. However, in this work, all three Chinese subspecies are considered as a single subspecies, and a taxon treated by Grieshuber (2014) as a synonym is revalidated as a distinct subspecies. In terms of ♀ wing-pattern, populations from a vast area spanning Wuqia Pamir in the southwest to the Borohoro Mountains in the northeast exhibit remarkable uniformity. Populations from the Balluk, Narat, Bogda, Karlik, Saur, and Altai Mountains (excluding southeastern Altai) often appear slightly paler in ♀ than those from the aforementioned regions, but these differences are subtle, inconsistent, and not diagnostically significant. Preliminary analysis of DNA sequence data does not support a division between these populations.
However, as discussed earlier, some populations in southeastern Altai exhibit a high percentage of ♀ individuals resembling *C. chrysotheme* (Esper), and initial DNA sequence analysis appears to support a distinction between these southeastern Altai populations and all others (fig. 36). The correct name for these southeastern Altai populations may be *C. thisoa cryptochrysa* Yakovlev, 2006.

The subspecific classification of this variable species remains problematic, as a small percentage of *C. thisoa cryptochrysa* Yarkovlev ♀♀ are morphologically indistinguishable from the palest specimens of *C. thisoa aeolides* Grum-Grshimailo, particularly those from the northern Altai region historically identified as *C. thisoa nikolaevi* Korshunov. To resolve this taxonomic uncertainty, additional DNA analyses incorporating multiple gene sequences are required.

***Colias thisoa aeolides* Grum-Grshimailo, 1890**

"*Colias Thisoa* var. *Aeolides*" Grum-Grshimailo, 1890: 346-347.

TL: Pamir...alaiennes, ...Trans-Alai et...Pierre le Grand. Grieshuber et al. (2012) clarified 7 different TLs from Kyrgyzstan and 1 from Tajikistan (Peter I Mts.).

Type material: The syntype illustrations consist of: one pair (ZMKU) in Tshikolovets (1997, 2003); 3 ♀♀ (ZMKU, ZISP) in Tshikolovets (2005b); and two pairs in Grieshuber et al. (2012).

Synonym. "*C. thisoa* forme *urumtsiensis*" Verity, 1907: pl. XLIV, figs. 18, 20-21 (synonymized by Tshikolovets, 2005b).

TL: Ouroumtsi, Tian-chan sept. Grieshuber et al. (2012) suggested that the type series was collected from the Bogda region, a conclusion with which the author concurs. Notably, there are no documented records of this species from the mountain ranges west of the flat river valley depression surrounding Urumqi.

Type material: 2 ♂♂, 1 ♀ syntypes were illustrated in original description (Verity, 1907); A pair of syntypes (ZMKU) were figured by Tshikolovets (2005b); 1 ♂, 3 ♀♀ syntypes (ZMKU) were figured by Grieshuber et al. (2012).

Synonym. "*C. thisoa nikolaevi*" Korshunov, 1998: 14 (synonymized by Gorbunov, 2001 and Tshikolovets et al., 2002).

TL: Altai, Kurai, ...Tyurgono.

Type material: Male holotype (SZMN) was figured by Tshikolovets, Yakovlev & Kosterin (2009).

Synonym. "*Colias thisoa irtyschensis* subspec. nov." Lukhtanov, 1999: 135-138, pl. 18, figs. 17-20 (synonymized with *nikolaevi* by Grieshuber & Lamas, 2007).

TL: Kasachstan, Ust-Kamenogorsk Gebiet, Altai, Kalba-Gebirge, Tainty.

Type material: Two pairs of syntypes (ZISP) were illustrated by Grieshuber et al. (2012).

Material. 1 ♂ (CHH), Torugart, Wuqia, 3400 m, 1.VIII.2022, H. Huang leg.; 14 ♂♂, 7 ♀♀ (CHH), Uqitax, Wuqia, 3100-3200 m, 2.VIII.2022 & 25-26.VI.2024, H. Huang leg.; 6 ♂♂, 3 ♀♀ (CHH), Guozigou, Borohoro Mts., 2100-2300 m, 21-23.VI.2019, H. Huang & S.-Y. Lang leg.; 3 ♂♂, 1 ♀ (CHH), Balluk Mts., Tuoli, 2000-2200 m, 25-26.VI.2022, H. Huang leg.; 2 ♂♂, 1 ♀ (CHH), N Hefeng, Saur Mts., 2100-2300 m, 19.VII.2022, H. Huang leg.; 6 ♂♂, 1 ♀ (CHH), Awusqi, between Tarbagatai and Saur, 2000-2400 m, 11.VI.2022, H. Huang leg.; 5 ♀♀ (CHH), Baihaba, Altai Mts., 1800-1900 m, 9.VI.2022, H. Huang leg.; 6 ♂♂, 1 ♀ (CHH), Bayinbluk, 2600-2800 m, 3 & 24.VII.2022, H. Huang leg.; 1 ♀ (CHH), S Bogda, Baiyanggou, 2800 m, 18.VIII.2024, H. Huang leg.; 1 ♂, 3 ♀♀ (CHH), Yiwu, Hami area, Karlik Mts., 2700-2950 m, 7.VII.2022, H. Huang leg.

Remarks. The taxonomic analysis reveals that populations from the Bogda and Karlik Mountains cannot be reliably distinguished from those inhabiting the Altai (excluding southeastern Altai), Saur, Balluk, and Eren Habirga Mountains, even when examining extensive specimen series. Although a potential biogeographic boundary appears to exist along the 82nd meridian east, characterized by consistently darker ♀ colouration in western populations compared to their eastern counterparts, molecular analyses of two mitochondrial COI gene fragments (1421 bp) and two nuclear EF1-alpha gene fragments (1016 bp) fail to support this apparent division. Given that the observed ♀ colouration differences between western and eastern populations are minor, subtle, and inconsistent, the author proposes treating these populations as a single subspecies. However, further comprehensive studies incorporating additional specimens and multiple genetic markers are necessary to validate this taxonomic interpretation.

***Colias thisoa cryptochrysa* Yakovlev, 2006 stat. rev.**

"Colias thisoa cryptochrysa Yakovlev, ssp. n."Yakovlev in Yakovlev & Doroshkin, 2006: 18, pl. II, figs. 4-6; Grieshuber & Lamas, 2007: 162, synonymy for *Colias thisoa nikolaevi* Korshunov; Tshikolovets, Yakovlev & Balint, 2009: 73, synonymy for *Colias thisoa aeolides* Grum-Grshimailo, pl. IX, figs. 4-5 & 7-8 for holotype and paratypes.

TL: W. Mongolia, Bayan-Ulegei aimak, middle stream of Elt-Gol river (Kara-Irtys basin), 2100-2300 m.

Type material: Male holotype (coll. Yakovlev) and 2 ♀♀ paratypes were figured in original description; ♂ holotype and 3 ♂♂, 1♀ paratypes were also figured by Tshikolovets, Yakovlev & Balint (2009).

Material. 1 ♀ (CHH), Sandaohaizi, Qinghe, SE Altai, 2400 m, 15.VII.2022, H. Huang leg.; 1 ♂, 2 ♀♀ (CXR), Sandaohaizi, 2400-2500 m, 29.VI.2017, R. Xing leg.

Remarks. As previously noted, a substantial proportion of ♀♀ in this subspecies resemble the dark form of *C. chrysotheme* (Esper). However, a minor percentage remain morphologically indistinguishable from typical ♀♀ of *C. thisoa aeolides* Grum-Grshimailo found in adjacent regions of the northern Altai. Future studies incorporating expanded DNA sequence analyses of additional specimens are required to resolve this taxonomic ambiguity.

***Colias marcopolo* Grum-Grshimailo, 1888**

"*Colias Marco-Polo* m." Grum-Grshimailo, 1888: 304-305

TL: Hindukush orient. Grieshuber et al. (2012) interpreted TL as Beik Pass between China and Tajikistan.

Type material: Two pairs of syntypes were figured by Grum-Grshimailo (1890); 3 ♂♂, 6 ♀♀ syntypes were figured by Verity (1908, 1911); One pair of syntypes (ZMKU) were figured by Tshikolovets (1997); two pairs of syntypes (NHML) were figured by Grieshuber et al. (2012).

Material. 1 ♂, 1 ♀ (CXR), Wakhan Corridor, 4700 m, 20.VII.2023, R. Xing leg.

Remarks. The collection site is currently restricted to unauthorized visitors under joint jurisdiction of both government and military authorities. Consequently, only Mr. R. Xing obtained special permission to conduct a four-day collecting expedition in this area, during which he successfully acquired a pair of specimens. These specimens will be documented in a forthcoming collaborative publication.

***Colias eogene* C. Felder & R. Felder, 1865** (fig. 19-20)

"*Colias eogene* nobis" C. Felder & R. Felder, 1865: 196-197, pl. 27, fig. 7.

"*Colias eogene* C. & R. Felder" Wu & Hsu, 2017: 0315, record for Xinjiang, 0317- fig. 20 for ♂ from Taxkorgan, Xinjiang.

TL: Himalaya.
Synonym. "*Colias eogene shandura*, nov." Evans, 1926: 713 (synonymized by Grieshuber & Lamas, 2007).
TL: Chitral NR (Lake Shandur).
Synonym. "*Colias Eogene* forme *Elissa*" Grum-Grshimailo, 1890: 332-333 (synonymized by Tshikolovets, 2003).
TL: Pamir septentrionales. Grieshuber et al. (2012) interpreted TL as Archa Bash and Agujurma Pass, W Alai.
Synonym. "*Colias Eogene* forme *Erythas*" Grum-Grshimailo, 1890: 330-332 (synonymized with *eogene* by Tshikolovets, 2003, and with *elissa* by Grieshuber & Lamas, 2007).
TL: Hindou-Kouch. Grieshuber et al. (2012) interpreted TL as Beik Pass between China and Tajikistan.
Synonym. "*Colias eogene francesca*, subsp. n." Watkins, 1927: 99-100 (synonymized by Tshikolovets & Pages, 2016).
TL: Skoro La, Baltistan.
Synonym. "*Colias eogene ericae* Peschke, subsp. nova" Peschke, 1934: 431 (synonymized with *francesca* by Grieshuber & Lamas, 2007, and with *eogene* by Tshikolovets & Pages, 2016)
TL: Dardistan, Dubunni-Berge.
Material. 6 ♂♂, 5 ♀♀ (CHH, CLP), Irkeshtam, Wuqia, 3400-3580 m, 18-23.VII.2019, H. Huang, P. Li & S.-Y. Lang leg.; 2 ♂♂, 4 ♀♀ (CHH), Uqitax, 3100 m, 2.VIII.2022, H. Huang leg.; 34 ♂ ♂, 11 ♀♀ (CHH, CDL), Uqitax, 3100-3250 m, 2.VIII.2022, H. Huang & L. Ding leg.; ♂ (photos; CXR), Mingtiegai Pass, VII.2023, R. Xing leg.; 1 ♂ (photos; CXR), Maeryang Pass, VII.2023, R. Xing leg.
Remarks. Nearly all taxa under this species have been regarded by various authors as synonyms of the nominotypical subspecies. While Grieshuber (2014) maintained the recognition of ssp. *elissa* Grum-Grshimailo and ssp. *francesca* Watkins, he notably commented that "most *elissa* specimens, especially from Ladakh populations, are impossible to distinguish from nominotypical *eogene*, therefore *elissa* could be just a junior synonym". Furthermore, he observed that "there is a huge range of variation in the intermediate zone between the subspecies *eogene* and *francesca*, both within and between populations, making it difficult to assign such populations to one of the two subspecies".
To investigate these taxonomic relationships, the author conducted genetic sequencing of two specimens from the geographical extremes of the distribution range: one from Pulan near the China-Nepal border (southernmost limit) and another from Uqitax, Wuqia (northernmost limit). The analysis (fig. 37- red section) revealed minimal genetic divergence in two mitochondrial COI gene fragments (1421 bp). This molecular finding does not support a subspecific classification. Nevertheless, definitive taxonomic resolution requires comprehensive analysis of additional specimens across multiple genetic loci.

***Colias arida arida* Alphéraky, 1889** (fig. 21-22, 25)

"Colias Eogene var. *Arida"* Alphéraky, 1889: 76.
TL: ... Lob-Noor et l'Aksu. Grieshuber et al. (2012) interpreted TL as 20-25 km south or southwest of Polu (36.1833 N, 81.4833 E) in Kunlun Mts.
Type material: ♂ lectotype (ZISP) was designated and illustrated by Rose & Schulte (1992), with subsequent illustrations published by Grieshuber et al. (2012) showing the lectotype together with 3 ♂♂ paralectotypes. High-resolution images of the lectotype and 5 ♂♂ paralectotypes have been made digitally accessible through Grieshuber's online repository.
Synonym. "*Colias Eogene* var. *flavescens*" Rühl, 1893: 161 (synonymized by Grieshuber & Lamas, 2007).
TL: Not stated. Grieshuber et al. (2012) inferred the type locality as the Kunlun Mountains based on morphological examination of the holotype specimen.
Type material: ♂ holotype (MNHU) was identified and illustrated by Grieshuber et al. (2012).
Remarks: ♂ holotype shows complete morphological congruence with ♂♂ of *C. arida arida* Alph. As stated by Grieshuber (2014), Korb (2014) unnecessarily introduced a new name, *hisilomeanus* Korb, 2014 for this taxon.
Synonym. *"C. eogene*, Felder var. *aphrodite*, Deck." Verity, 1907: pl. XLIII, partim on fig. 28 (synonymized by Grieshuber et al., 2012).
TL: Mountains near Aksu River (44 N, 80 E). Grieshuber et al. (2012) subsequently interpreted the TL as the Kunlun Mountains.
Type material: ♂ lectotype (ZMKU) was designated and illustrated by Grieshuber et al. (2012).
Remarks: Through personal communication, a colleague raised the taxonomic possibility that the lectotype of *C. eogene aphrodite* Verity may belong to *C. staudingeri* Alph. rather than *C. arida* Alph. Comparative examination revealed three diagnostic characters distinguishing ♂ *C. arida* Alph. from *C. staudingeri* Alph: 1) more distinctly defined blackish-gray subbasal and antediscal dusting in space 1c on the hindwing upperside; 2) a consistently broader marginal band on the hindwing upperside, extending further along the costa and particularly pronounced in space 6; 3) clearly pale-outlined veins throughout the submarginal area on the hindwing underside.
Synonym. "*Colias muratai* sp. n." Iwamoto, 2006: 17, 19-20, figs. 1-4 (synonymized by Grieshuber & Lamas, 2007).
TL: Mt. Kaxtax 3800 m, Kunlun Mts.
Type material: ♂ holotype, 1 ♀ paratype were illustrated in original description.
Synonym. "*Colias amanonis* sp. n." Iwamoto, 2006: 17, 19-20, figs. 5-6 (synonymized by Grieshuber & Lamas, 2007).
TL: Mt. Kaxtax 3800 m, Kunlun Mts.
Type material: ♂ holotype was illustrated in original description.
Remarks: Molecular analysis included 1 ♂ specimen (fig. 21- AA1) morphologically matching the holotype form of *Colias amanonis* Iwamoto. The results demonstrated no genetic differentiation between this form and the typical phenotype (fig. 38).
Material. 15 ♂♂, 4 ♀♀ (CHH), 189 km S of Cele, C Kunlun Mts., 3200-3300 m, 23.VII.2024, H. Huang leg.
Remarks. The taxonomic confusion surrounding this taxon was resolved by Grieshuber et al. (2012). Beyond the type series, the second known set of specimens was collected by Milan Kopp along a route extending from Cele southward into the Kunlun Mountains (Grieshuber et al., 2012). The third known series was obtained by Nobuo Murata on the northern slopes of Mt. Kashtash, approximately 46-47 km east of the TL. Murata's specimens were initially misclassified by Iwamoto as two novel species, which were later synonymized with *C. arida arida* Alphéraky.
The new collection site reported in this study was first discovered by Prof. Shao-Shan Wang (Shihezi University, Xinjiang), who generously provided the collection data. This locality lies between the TL and Kopp's site, meaning all four known occurrences are clustered within a narrow 150 km west-east range along the northern foothills of the central Kunlun Mountains.
Specimens from the newly documented site reveal considerable individual variation, particularly in forewing shape (ranging from

pointed to rounded), the width of the black marginal border on the wing uppersides, and the presence or absence of pale submarginal spots on the hindwing upperside in ♂♂.
This subspecies is readily distinguished from its eastern counterpart, *C. a. cakana* Rose & Schulte, 1992. Males exhibit a richer, more orange ground colour on the upperside, while ♀♀ occur exclusively in the red morph, characterized by significantly broader black borders covering the outer half of both wings. Molecular analyses of two mitochondrial COI gene fragments (1,421 bp), one nuclear Rps5 fragment (593 bp), and two nuclear EF1-alpha fragments (1,016 bp) robustly support the conspecificity of these subspecies.

***Colias wanda yangguifei* R.-X. Huang & Murayama, 1992**

"Colias chrysotheme yangguifei ssp. nov." Huang & Murayama, 1992: 4-5, partim on ♂♂, 2- fig. 8 for ♂ holotype.
"*C. stoliczkana yangguifei*" Hoshiai, 1993: 15, taxonomic note.
"*Colias wanda yangguifei*" Grieshuber & Lamas, 2007: 164, catalogue; Grieshuber et al., 2012: 240, pl. 23, figs. 13-16 for 2 ♂♂, 2 ♀♀ from S of Milan; Huang & Song, 2022: 454, discussion on TL, fig. 73 for ♂ holotype.
TL: Aqikfu, Aljin, East Kunlun. Huang & Song (2022) clarified the TL as a camp of Kalachuka near the co-ordinates 36.9365N, 88.6674E.
Type material: ♂ holotype (BLXU) was illustrated in the original description as a black-and-white photograph and in Huang & Song (2022) as colour photographs.
Material. 2 ♂♂, 1 ♀ (CHH), Tanbei-xuefeng, 62 km S of Mangya, 21.VII.2021, 4939 m, R. Xing leg.; 1 ♂ (CHH), No. 76 Peak, 188 km W of Mangya, Altun Shan, 4700 m, 27.VII.2021, R. Xing leg.; 2 ♂♂ (CHH), Qimantag Mts., 11 km N of Ayakekum Lake, 5100 m, 19.VII.2021, R. Xing leg.
Remarks. Huang & Song (2022) identified the TL as Kalachuka in the eastern Kunlun Mountains, based on earlier reports by Huang and colleagues in Chinese publications. However, Huang & Song (2022) may have incorrectly assumed that the holotype from the eastern Kunlun is more closely related to *C. wanda wanda* Grum-Grshimailo, 1907 from Qinghai than to populations from the Altun Shan and Qimantag Mountains. According to R. Xing (personal communication), although butterfly biotopes in the eastern Kunlun Mountains are wetter than the arid Altun Shan region and show some faunal differences, the butterflies distributed across both areas demonstrate minimal variation between populations. Consequently, the author considers all populations from Altun Shan, Tanbeixuefeng, and Qimantag Mountains to belong to *C. wanda yangguifei* Huang & Murayama.
The genetic divergence in mitochondrial DNA among known subspecies of *Colias wanda* Grum-Grsh. appears to be remarkably limited (fig. 39).

***Colias l i n g* spec. nov.** (fig. 21)

Holotype ♂: China, Xinjiang, National Road 219, north of Mazha Daban, 4700-4770 m, 19.VII.2024, H. Huang leg., deposited in BSNU.
Paratypes: 13 ♂♂, 4 ♀♀ (CHH), same data as holotype; 3 ♂♂ (CHH), south of Mazha Daban, 4750 m, 20.VII.2024, H. Huang leg.; 3 ♂♂, 2 ♀♀ (CHH), north of Mazha Daban, 4800 m, 27.VII.2024, H. Huang leg.; 6 ♂♂, 2 ♀♀ (CHH), north of Mazha Daban, 4800 m, 13.VIII.2024, H. Huang leg.
Etymology. The species bears the name of a dear friend - the companion who walked beside the author on that first youthful journey from Ali to Kashgar in the summer of 1993, when he was just twenty.
Diagnosis. The new species is undoubtedly close to *C. stoliczkana* Moore, 1878 and *C. wanda* Grum-Grsh., but can be distinguished from both of the latter by the following combination of characteristics:
Male:
1) The upper side ground colour is markedly darker and clad with scattered blackish scales throughout.
2) All veins on the upper side of wings are more clearly and heavily outlined with blackish scales.
3) The hindwing upper side marginal border is more even in width overall, being wider at the apex than in other species.
Female:
4) All eight known specimens are in red form with reddish upper side ground colour.
5) The submarginal pale spots in the forewing upper side black border are incomplete in number and reduced in size.
Remarks. The ♂ of this new species exhibits significantly darker colouration compared to all other orange *Colias* species, including the large *C. adelaidae* Verhulst, 1991, making it immediately distinguishable. The ♀ resembles that of *C. stoliczkana miranda* Fruhstorfer, 1903 from Sikkim and NE Nepal, but can be reliably differentiated by its generally larger size and the presence of incomplete, reduced submarginal spots on the forewing upperside.
All ever-published taxa synonymized under *C. stoliczkana* Moore, 1878, *C. wanda* Grum-Grsh., and *Colias arida* Alph. have been carefully compared and found incompatible in both wing characters and zoogeography. It should be noted that *C. jommoseri* Miller, 2009, described from a single ♀ specimen from Bhutan, should be considered a synonym of *C. stoliczkana* Moore, as stated by Grieshuber et al. (2012).
As for the distribution map (fig. 45), the author follows Grieshuber et al. (2012) regarding the precise locations of TLs for *C. stoliczkana* Moore and *C. arida* Alph. As noted by Grieshuber et al. (2012), the original designation 'north of Changla' for the TL of *C. stoliczkana* Moore was erroneous.
Phylogenetic Analysis of Mitochondrial and Nuclear DNA Markers
Analysis of two mitochondrial COI gene fragments (1,421 bp) strongly supports the distinct species identities of *Colias arida* Alph., *C. wanda* Grum-Grsh., *C. stoliczkana* Moore, and *C. **ling*** **spec. nov.**, as these clades exhibit deep divergences with clear gaps between them on the COI gene tree (fig. 39).
Given potential incongruence between mitochondrial and nuclear DNA phylogenies, the author attempted to analyze three nuclear gene fragments (two EF1-α and one Rps5; total 1,609 bp). However, this failed to yield meaningful resolution (fig. 40). The data show that:
* All species display minor genetic differences.
* Each species except *C. stoliczkana* Moore (represented by only one specimen) exhibits variable genotypes at these nuclear loci.
* No clear species boundaries could be delineated based on the limited nuclear markers analyzed.
Our results suggest that:
1) Additional limited nuclear markers are unlikely to resolve these relationships.

2) Definitive resolution will require high-throughput sequencing (e.g., next-generation sequencing, NGS) of numerous nuclear loci. A combined analysis of both mitochondrial (1,421 bp) and nuclear (1,609 bp) datasets (total 3,030 bp) produced a phylogeny with all four species clearly differentiated (fig. 38). It suggests that *Colias* ***ling*** **spec. nov.** forms a sister taxon to *C. wanda* Grum-Grsh. This result is consistent with morphological comparisons, which indicate that *C. wanda* Grum-Grsh. is the most closely related species to *C.* ***ling*** **spec. nov.** based on wing size characteristics.
Field observations. This new species begins flying in mid-July, as the author did not encounter it during his visit to the biotope on 5-7 July 2024. A small proportion of ♀ individuals had already appeared by 19 July 2024. The author still collected some ♂♂ (all worn) in mid-August. The flight period appears to continue until late August.
The biotope consists of sloping meadows at 4700-4800 m altitude. The author failed to collect any other butterfly species at this site, except for one observation of a worn *Parnassius simo confusus* Bang-Haas, 1927 flying up the slope.

Colias wiskotti seres Grum-Grshimailo, 1890

"Colias Wiskotti var. seres" Grum-Grshimailo, 1890: 352-353.
"*Colias wiskotti* Staudinger" Wu & Hsu, 2017: 0311, 0312- fig. 6 for ♂ from Taxkorgan, 0313- fig. 7 for ♀ from Taxkorgan.
TL: Grieshuber et al. (2012) interpreted TL as the mountains around the valley to south of Taxkorgan (fig. 42).
Type material: ♀ lectotype (NHML) was designated and figured by Grieshuber & Worthy (2006). "None of the type-series ♂♂ has been found; they are presumed to be either lost or impossible to identify" (Grieshuber et al., 2012).
Material. 23 ♂♂, 21 ♀♀ (CHH), 33-44 km south Taxkorgan, 3450-3900 m, 4-8.VIII.2022, 17.VII-7.VIII.2024, H. Huang & Y.-H. Li leg..
Remarks. The author collected an excellent series of specimens from areas immediately adjacent to the TL, enabling clear differentiation between *C. w. seres* Grum-Grsh. and *C. w. chrysoptera* Grum-Grsh., 1888 based on the following diagnostic characters:
1) Prominent black smudges on the forewing underside (particularly in space 1b), present in both sexes of *C. w. chrysoptera* Grum-Grsh., are either greatly reduced or completely absent in *C. w. seres* Grum-Grsh.
2) The white ♀ morph occurs in *C. w. chrysoptera* Grum-Grsh. but is never found in *C. w. seres* Grum-Grsh.
It should be noted that Tshikolovets (2003) erroneously identified several specimens from the eastern distribution range of *C. w. chrysoptera* Grum-Grsh. as *C. w. seres* Grum-Grsh.

Colias staudingeri Alphéraky, 1881 (fig. 28)

Colias staudingeri staudingeri Alphéraky, 1881

"C. Staudingeri Alph. nov. sp.*"* Alphéraky, 1881: 368-373, pl. XIV, figs. 3-4.
"C. eogene, Felder var. *aphrodite*, Deck." Verity, 1907: pl. XLIII, partim on figs. 29-31 for ♀♀; Grieshuber et al., 2012: 49, partim on ♀ paralectotypes.
TL: Grieshuber et al. (2012) interpreted TL as 45 km NNE Narat (fig. fig. 42).
Type material: ♂ lectotype (ZISP) was designated and figured by Grieshuber et al. (2004) alongside 2 ♂♂. 4 ♀♀ paralectotypes. A pair of paralectotypes were illustrated by Tshikolovets (2005b). Male lectotype, 2 ♂♂, 3 ♀♀ paralectotypes were also figured by Grieshuber et al. (2012).
Synonym."*Colias Staudingeri* v. *Maureri* Stgr." Staudinger, 1901: 18 (synonymized by Grieshuber et al., 2012).
TL: unverifiable.
Type material: ♂ lectotype (MNHU) was designated and illustrated by Grieshuber et al. (2012).
Remarks. The TL recorded in the original description is inconsistent with the morphological characteristics of the lectotype, which shows no discernible differences from typical ♂ specimens of *C. s. staudingeri* Alph.
Synonym. "*Colias Staudingeri* Alph. und var. *Emivittata* Ver." Wagner, 1913: 59 (synonymized by Grieshuber, 1997).
TL: Sary-Dschas, E Kyrgyzstan (for Wagner's specimens) and Aksu (for Verity's specimen).
Type material: Only Verity's specimen (ZMKU) remains traceable and serves as a syntype. This specimen was illustrated by Verity (1908), Grieshuber et al. (2004), and subsequently by several other authors.
Remarks. Tshikolovets (2005b) illustrated a few ♂♂ from Sary-Dzhaz, one of the TLs.
Synonym. "*Colias Staudingeri* f. *Kuekunthali* Niepelt f. n." Niepelt, 1914: 45, pl. 4, fig. 19 (synonymized by Grieshuber & Lamas, 2007).
TL: Tianschan-Gebirge, Turkestan, no details.
Type material: Male holotype (depository unknown) was figured in original description.
Material. 14 ♂♂, 6 ♀♀ (photos only; ZFMK), E Kyrgyzstan; 11 ♂♂, 9 ♀♀ (photos only; ZFMK), near Shengli-daban, or 90 km NE Baluntai, Borohoro Mts.; 1 ♂, 1 ♀ (CXR), Houxia, near Shengli-daban, S Urumqi, VI.2018, R. Xing leg.; 4 ♂♂ (photos only; ECSU), Xiata, Zhaosu, north slope of Halke Shan; 3 ♂♂, 1 ♀ (CXR, CHH), Maidantag Mts., S Akqi, 3500 m, 7.VII.2022 & 23.VI.2023, R. Xing leg.
Remarks. There is a good series of specimens in the previous Rose's collection (now in ZFMK), collected from E Kyrgyzstan and S Urumqi, covering all the forms in each locality.
A small series of specimens were collected by Mr. R. Xing from Maidantag Mts. in Akqi area, most of which are indistinguishable from the populations from S Urumqi. However, a ♂ (fig. 28-SS1) is darker than usual, closely resembling the recently described *Colias delshade* Karbalaye & Grieshuber, 2019 from Afghanistan.
For amateur collectors, a note is necessary on the diagnostic characters separating ♂♂ of *C. staudingeri staudingeri* Alph. from *C. thisoa aeolides* Grum-Grsh. These two taxa have overlapping ranges in the Chinese Tian Shan, though they fly at different elevations. Some ♂♂ specimens with pale submarginal spots on the forewing upperside are difficult to identify. *C. staudingeri staudingeri* Alph. can be distinguished from *C. thisoa aeolides* Grum-Grsh. in ♂♂ by a usually shorter hindwing anal margin, a more convex forewing termen, a less pointed forewing apex, a more black-dusted underside ground colour, and a consistently shorter hindwing marginal band.

Colias staudingeri pamira Grum-Grshimailo, 1890

"Colias Staudingeri Alph. var. *Pamira"* Grum-Grshimailo, 1890: 334-335, pl. IV, figs. 2 a-c.
TL: Grieshuber et al. (2012) interpreted TL as ca. 20 km S of Daraut-Kurgan, Altyn Dara River valley, Kara-Ssu source and near the Ters-Agar Pass, Upper Aram Kungei River valley, western Transalai, Kyrgyzstan.
Type material: Three pairs of syntypes (ZISP, NHML, ZMKU) were illustrated in Grieshuber et al. (2012).

Synonym."*C. pamiri* Alph." Ruhl, 1893: 164 (synonymized by Rober, 1907, Tshikolovets, 1997 and Grieshuber & Lamas, 2007)
TL: Grieshuber et al. (2012) interpreted TL as ca. 20 km S of Daraut-Kurgan.
Type material: None of the syntypes (one in ZMHU) has been figured.
Synonym. "*C. staudingeri,* Alph. var. *alexandrina* Gr." Verity, 1908: pl. XLV, fig. 9 (first synonymized by Talbot, 1932-1935, and this synonymy was confirmed by Grieshuber et al., 2012).
TL: Monts Alexandre. Tshikolovets' (2005b) interpretation of the TL on the map was denied by Grieshuber et al. (2012), who deduced that the exact position of the TL is not definable.
Type material: The ♂ lectotype was designated and figured by Grieshuber et al. (2012).
Material. 1 ♂ (CHH), Irkeshtam, 3380 m, 23.VII.2019, H. Huang leg.
Remarks. The identification of the unique specimen recorded here - new to the Chinese fauna - was confirmed by mitochondrial COI gene sequencing (fig. 37).

***Colias romanovi* Grum-Grshimailo, 1885** (fig. 29)

"C. romanovi m." Grum-Grshimailo, 1885: 229, footnote 16.
TL: six different localities in the Alai and Transalai Mts.
Type material: ♂ and ♀ syntypes were summarized and figured in Grieshuber et al. (2012).
Synonym. "*Colias romanovi seravschana* subspec. nov." Lukhtanov, 1999: 135, 138-139 (synonymized by Tshikolovets, 2003 and Grieshuber & Lamas, 2007).
TL: 8 km south of Oburdan, Dascht, Tajikistan.
Type material: ♂ holotype was figured by Grieshuber et al. (2012).
Material. 9 ♂♂, 1 ♀ (CHH, CLP), Irkeshtam, 3500 m, 19-23.VII.2019, H. Huang & P. Li leg.; 1 ♂ (CHH), Irkeshtam, 3500 m, 4.VIII.2022, H. Huang leg.
Remarks. This species is new to Chinese fauna. The previous record by Zhang et al. (1991) from the Altai area is a misidentification of *C. thisoa aeolides* Grum-Grsh.

***Colias erschoffii* Alphéraky, 1881** (fig. 30-31)

"Colias Erschoffii Alph. nov. sp." Alphéraky, 1881: 362-365, pl. XIV, fig. 1-2.
TL: Grieshuber et al. (2012) interpreted TL as four localities in the Borohoro, Narat and Ketmen Mts.
Type material: ♂♂ and ♀♀ syntypes (ZISP, ZMHU) were figured by Tshikolovets (2005b), Grieshuber et al. (2012) and Tshikolovets et al. (2016).
Synonym. "*Colias Erschoffi variete Tancrei*" Austaut, 1890: 94 (synonymized by Grieshuber & Lamas, 2007).
TL: not stated. The ♂ holotype was labeled from Kouldja (Yining area).
Type material: ♂ holotype was figured by Grieshuber et al. (2012).
Material. 1 ♂, 1 ♀ (CHH), Balluk Mts., 5.VII.2021, R. Xing leg.; 23 ♂♂, 8 ♀♀ (CHH), Balluk Mts., 26.VI.-22.VII.2022, H. Huang & Y.-H. Li leg.
Remarks. During the author's initial expedition to the Yining area, this remarkable *Colias* species was not rediscovered. However, Mr. R. Xing unexpectedly collected a small series of specimens from the Balluk Mountains, located more than 180 km north of all previously known localities. The author subsequently visited this new site in 2022 and obtained a substantial series of specimens. This species shows a distinct preference for arid primary grassy slopes rather than the more common green meadows. It is probable that much of this specialized habitat in the Yining area has been degraded or destroyed.

***Colias regia* Grum-Grshimailo, 1887**

"*Colias regia* Grum-Grshimailo, 1887" Grieshuber, 2014: 75, record from China (SE Xinjiang?), giving no reference or figure.
Remarks. The record by Grieshuber (2014) merely suggests the potential occurrence of this species in China, as its known range in Kyrgyzstan extends along the entire frontier adjacent to Chinese territory. While it is reasonable to assume that the species may also occur in China, no verified specimens have been collected by Chinese researchers to date (based on the author's knowledge). Future discoveries may become more likely once national roads along the Chinese border are completed and made accessible to scientific exploration.

Postscript

Zhang et al. (1991) incorrectly recorded the following species in their paper due to misidentifications.
1) *"Colias fieldi* Menetries": Xinjiang (Zhang et al, 1991: 7)
The description of the recorded ♂♂ and ♀♀ specimens from Xinjiang suggests that this is a misidentification of *C. thisoa aeolides* Grum-Grsh.
2) "*Colias romanovi* Gr. Grsh": Kanas Lake of Altai (Zhang et al, 1991: 7)
The description of the recorded 1 ♀ from Kanas suggests that this is a misidentification of *C. thisoa aeolides* Grum-Grsh.
3) *"Colias croceus* Foure": Xinjiang (Zhang et al, 1991: 7-8)
The description of the recorded ♂♂ and ♀♀ specimens from Xinjiang suggests that this is a misidentification of the rare orange forms of *C. erate erate* (Esper).

R.-X. Huang et al. (2000) recorded the following species in their book, but most of the figures in the book came from foreign publications, foreign specimens or specimens from outside Xinjiang; they recorded many taxa which are definitely not known from Xinjiang, without giving any collecting data.
1) "*Colias berylla* Fawcett": Tianshan (R.-X. Huang et al., 2000: 23).
2) "*Colias sieversii* Grum-Grshimailo": Tianshan (R.-X. Huang et al., 2000: 23).
3) "*Colias heos* (Herbst)": Altai (R.-X. Huang et al., 2000: 24).
4) "*Colias alpherakyi* Staudinger": Aljinshan (R.-X. Huang et al., 2000: 25).
It is worth noting that R.-X. Huang & Murayama (1992) described the Xinjiang population of *Colias grumi* Alph. as *Colias alpherakyi aljinshana* R.-X. Huang & Murayama.
5) "*Colias tyche* Boeber": Altai (R.-X. Huang et al., 2000: 25).

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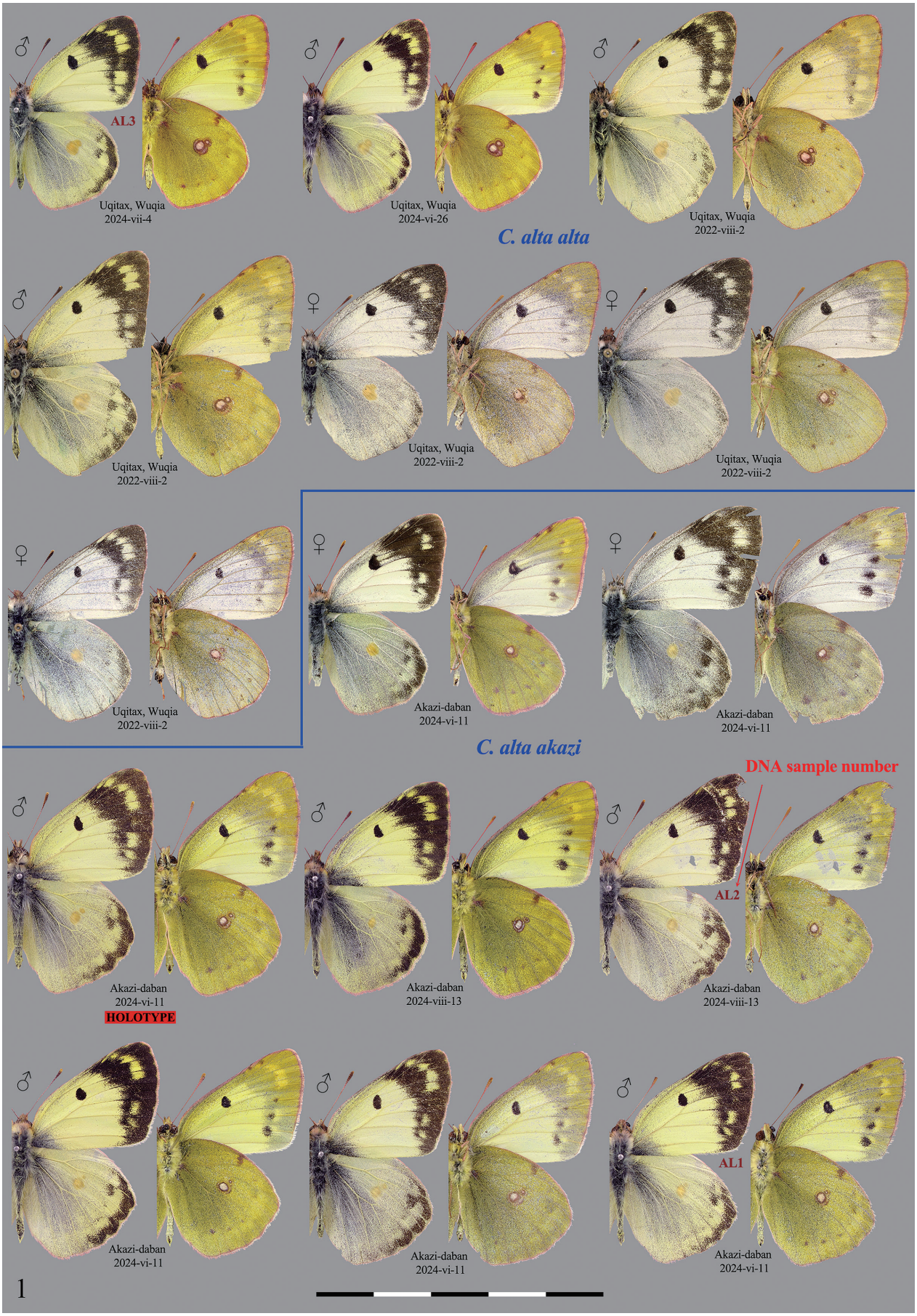

Fig. 1: Habitus of *Colias alta* Staudinger, 1886 under same scale (scale bar = 1 cm).

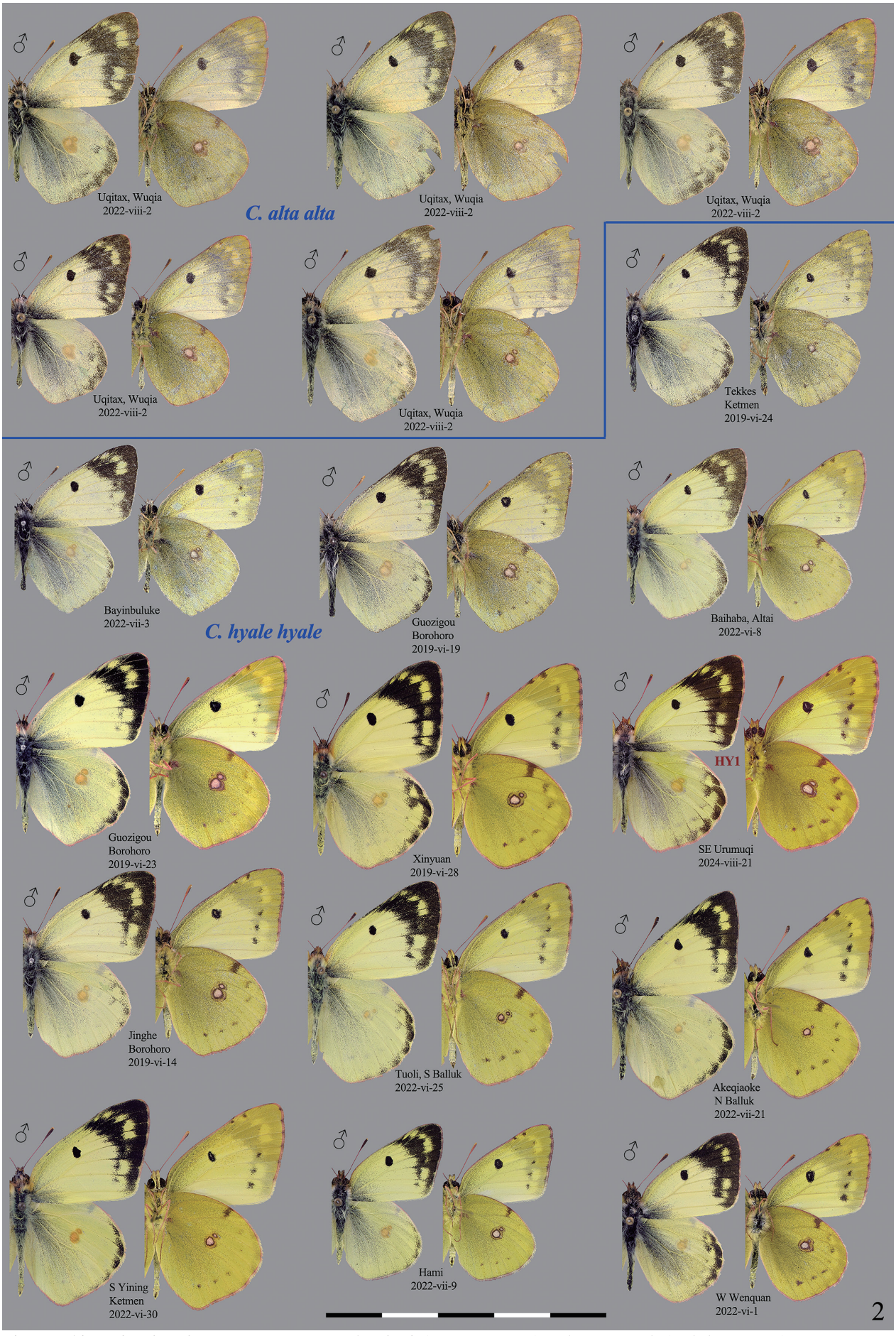

Fig. 2: Habitus of *Colias alta* Staudinger, 1886 and *C. hyale* (Linnaeus, 1758) under same scale (scale bar = 1 cm).

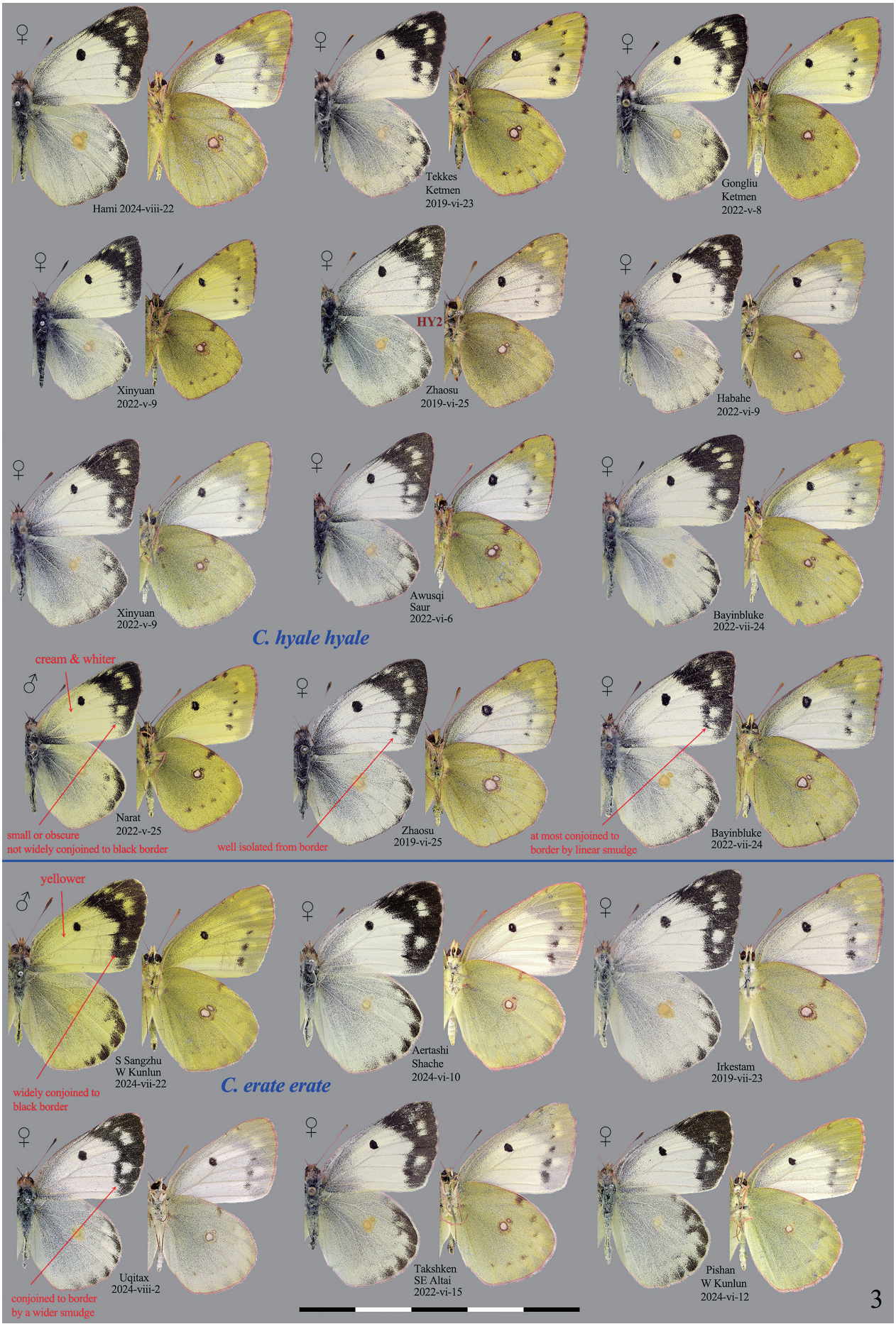

Fig. 3: Habitus of *Colias hyale* (Linnaeus, 1758) and *C. erate* (Esper, [1805]) under same scale (scale bar = 1 cm).

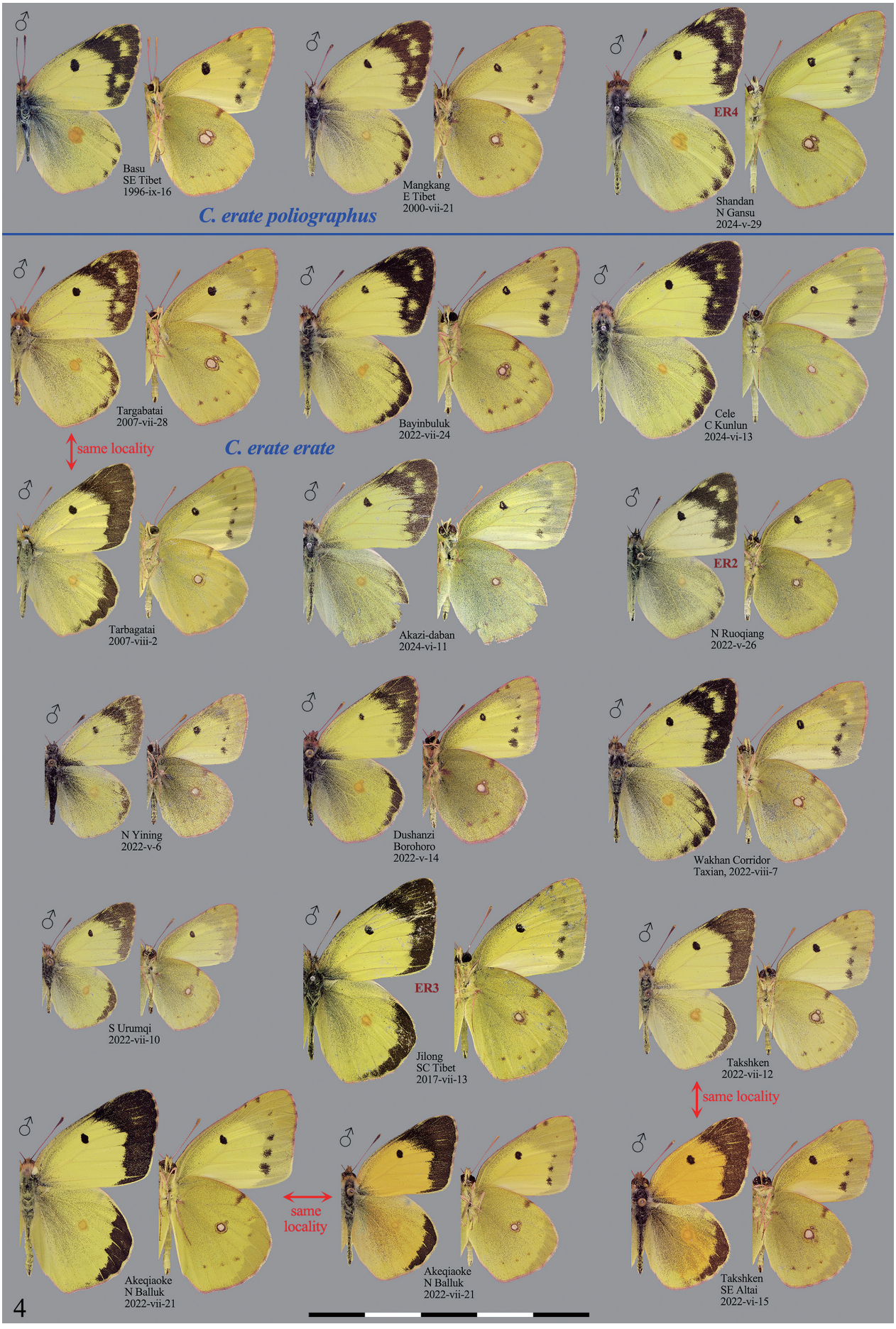

Fig. 4: Habitus of *Colias erate* (Esper, [1805]) under same scale (scale bar = 1 cm).



Fig. 5: Habitus of *Colias erate* (Esper, [1805]) under same scale (scale bar = 1 cm).

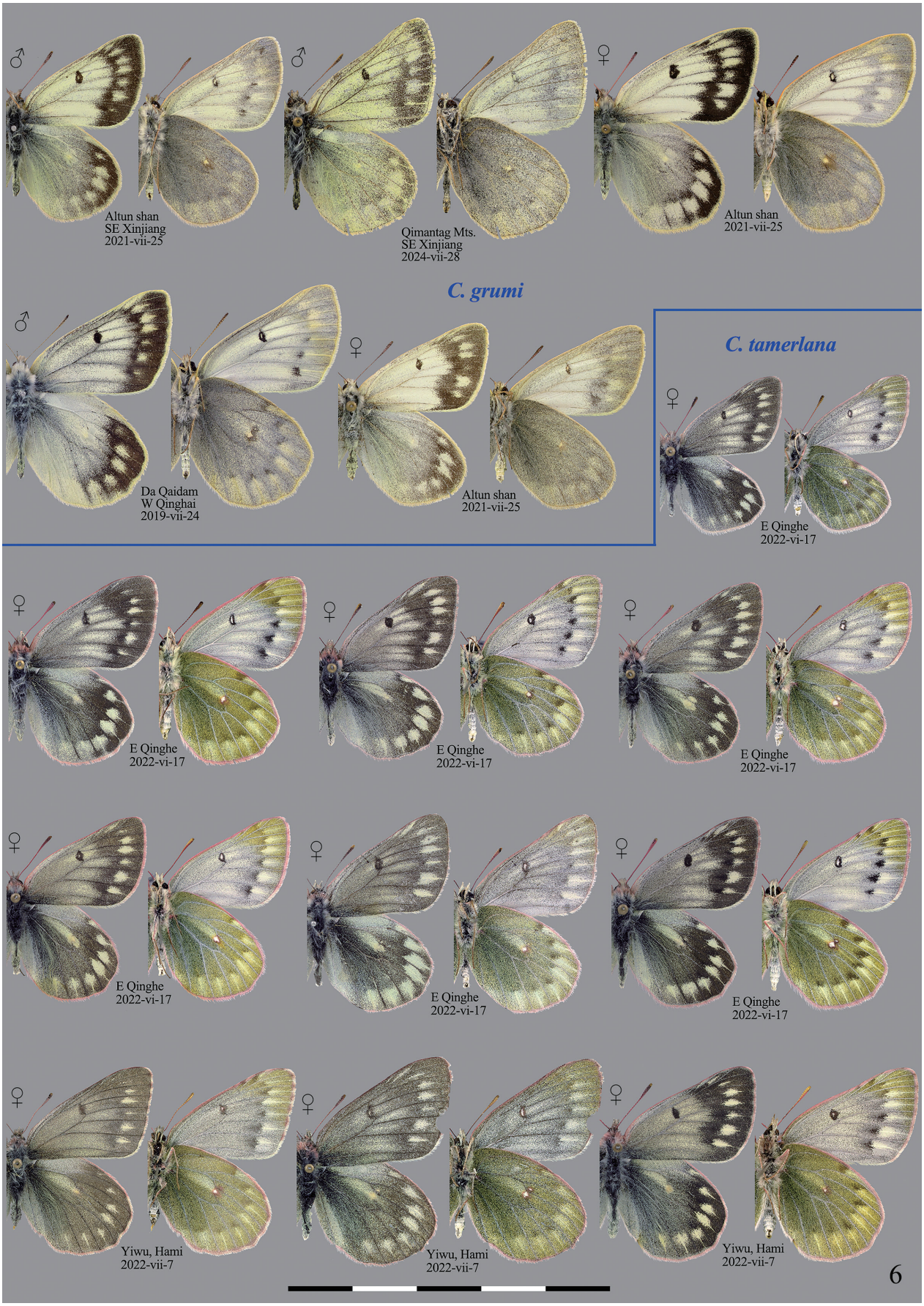

Fig. 6: Habitus of *Colias grumi* Alphéraky, 1897 and *C. tamerlana* Staudinger, 1897 under same scale (scale bar = 1 cm).

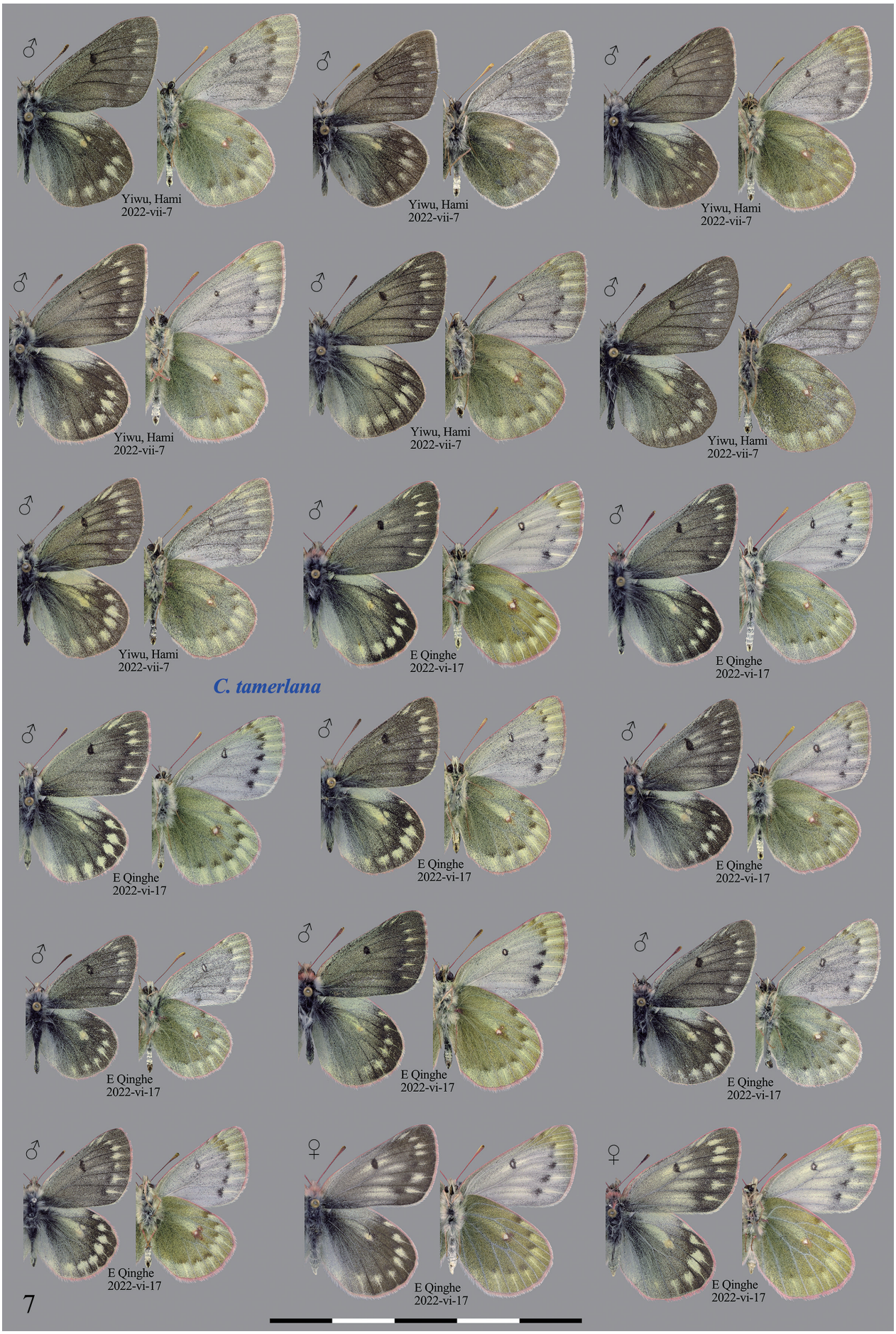

Fig. 7: Habitus of *Colias tamerlana* STAUDINGER, 1897 under same scale (scale bar = 1 cm).



Fig. 8: Habitus of *Colias cocandica* ERSCHOFF, 1874 under same scale (scale bar = 1 cm).



Fig. 9: Habitus of *Colias cocandica* Erschoff, 1874 under same scale (scale bar = 1 cm).



Fig. 10: Habitus of *Colias cocandica* Erschoff, 1874 under same scale (scale bar = 1 cm).



Fig. 11: Habitus of *Colias cocandica* ERSCHOFF, 1874 under same scale (scale bar = 1 cm).

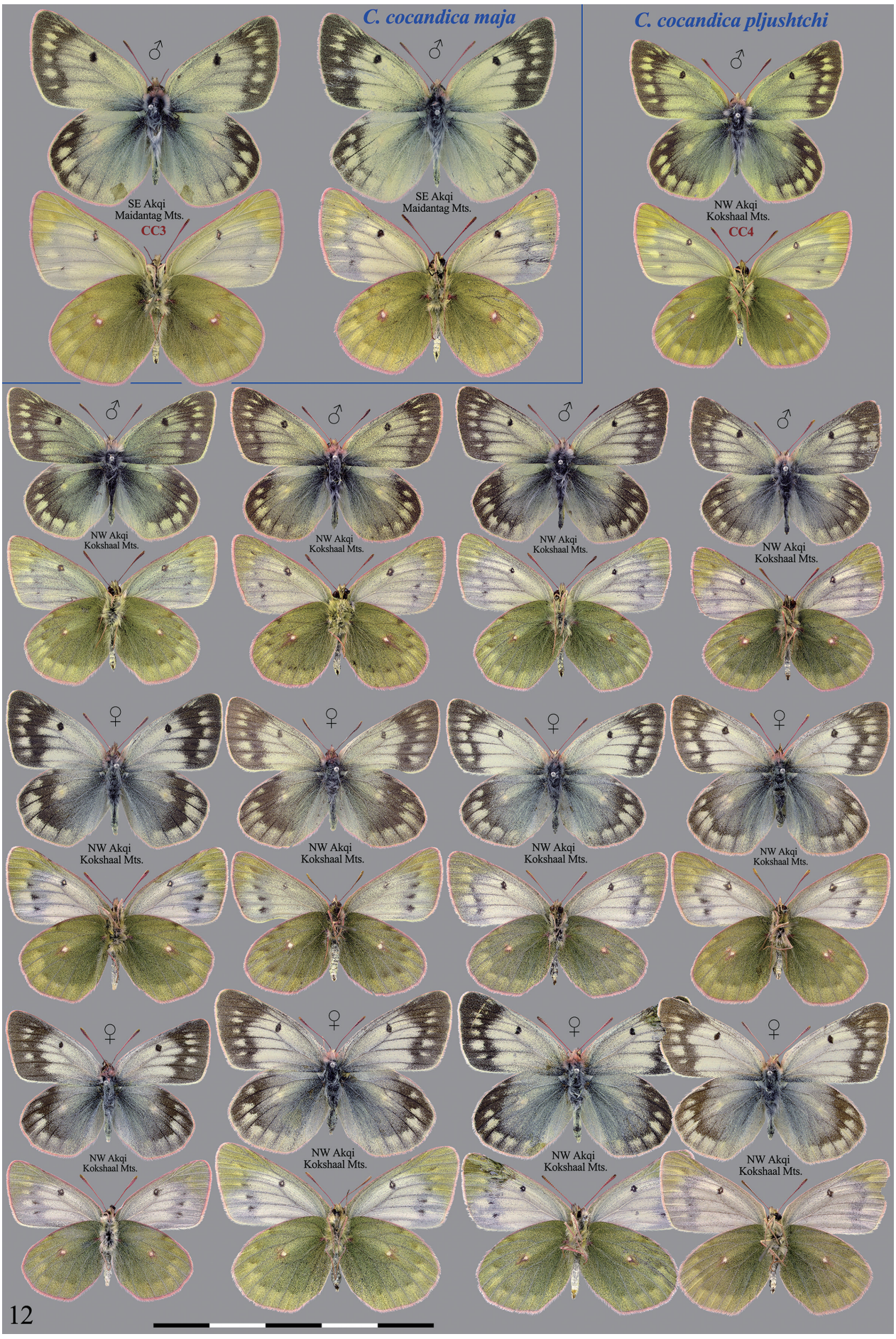

Fig. 12: Habitus of *Colias cocandica* ERSCHOFF, 1874 under same scale (scale bar = 1 cm).

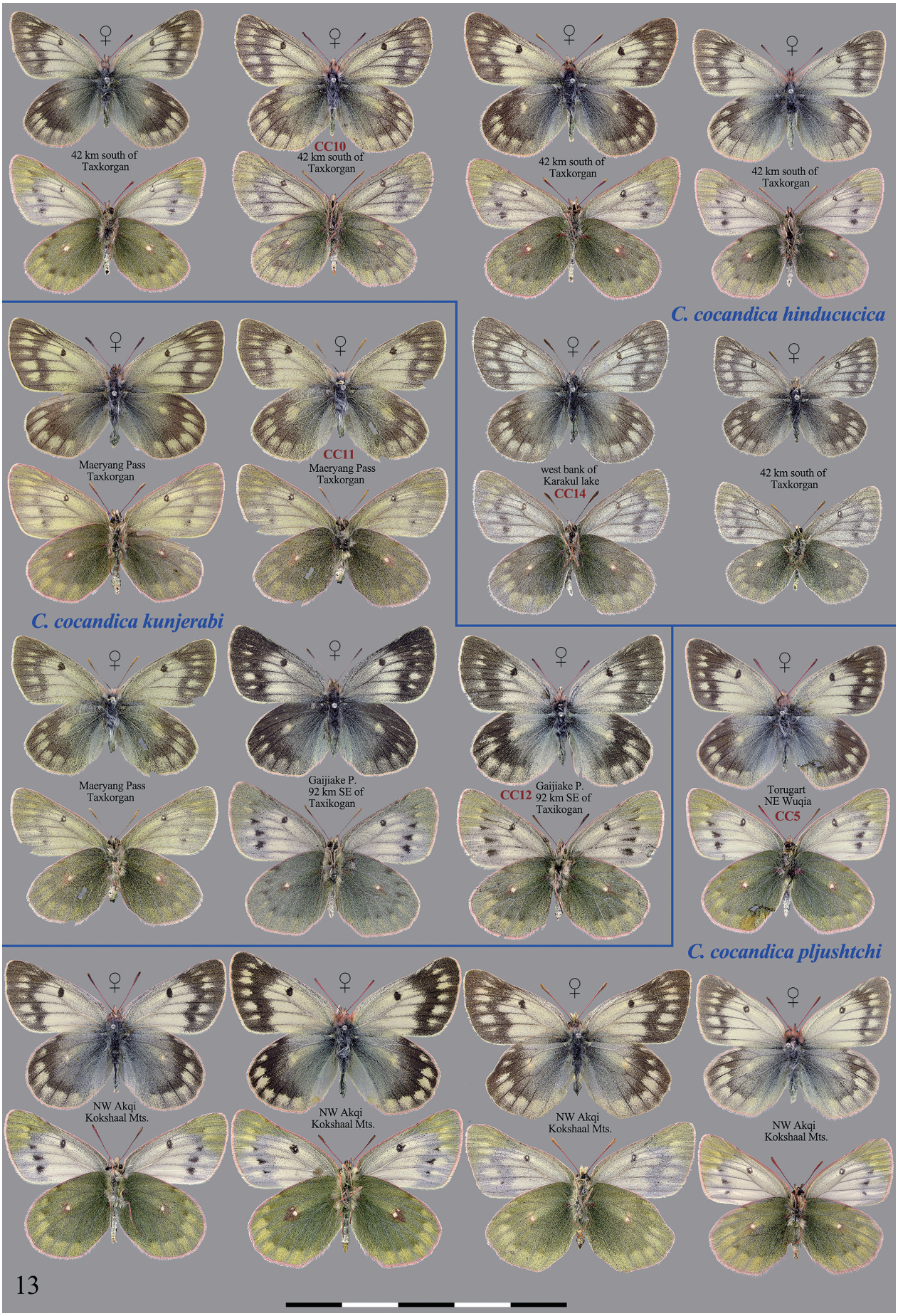

Fig. 13: Habitus of *Colias cocandica* Erschoff, 1874 under same scale (scale bar = 1 cm).



Fig. 14: Habitus of *Colias cocandica* Erschoff, 1874 under same scale (scale bar = 1 cm).

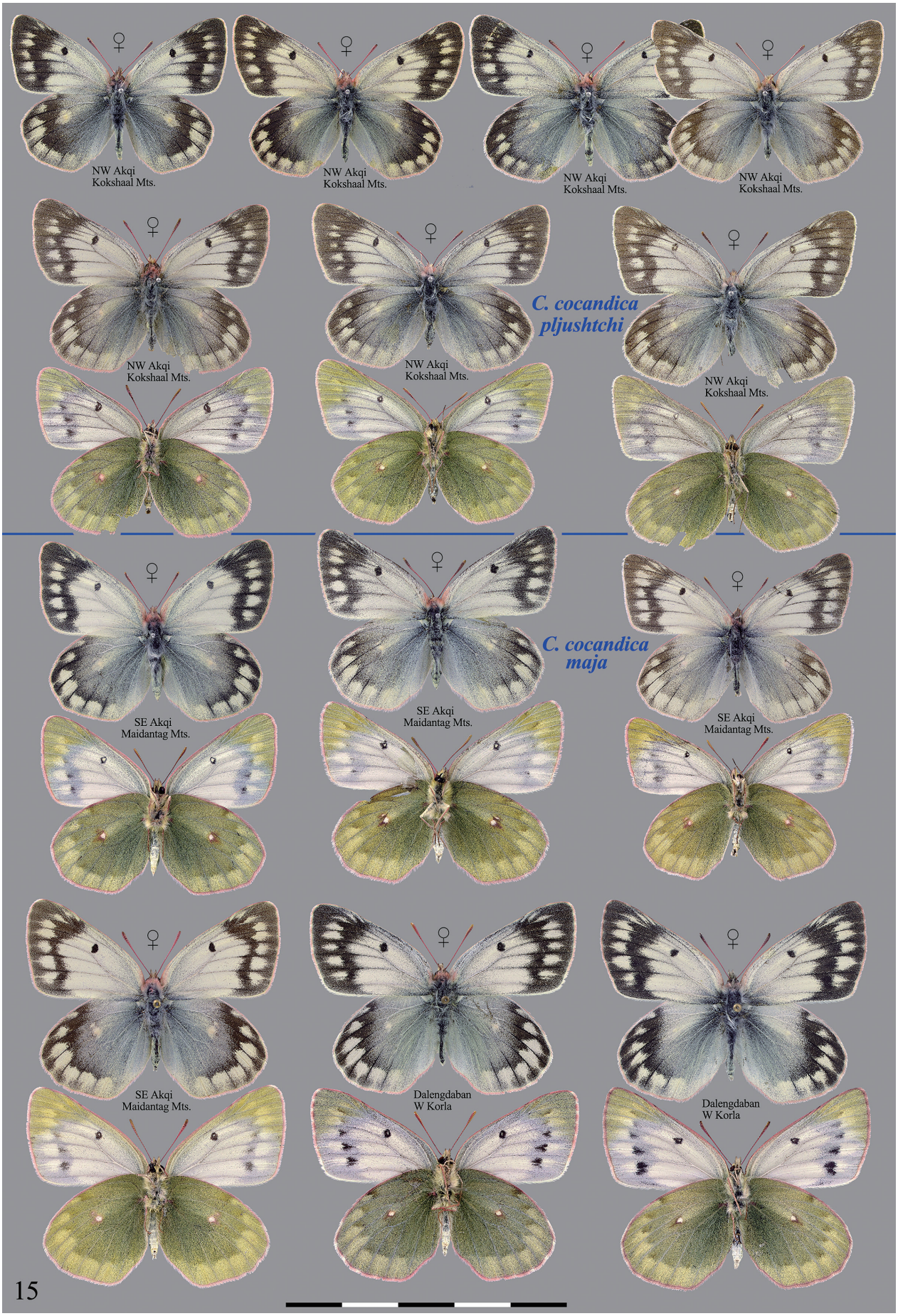

Fig. 15: Habitus of *Colias cocandica* Erschoff, 1874 under same scale (scale bar = 1 cm).

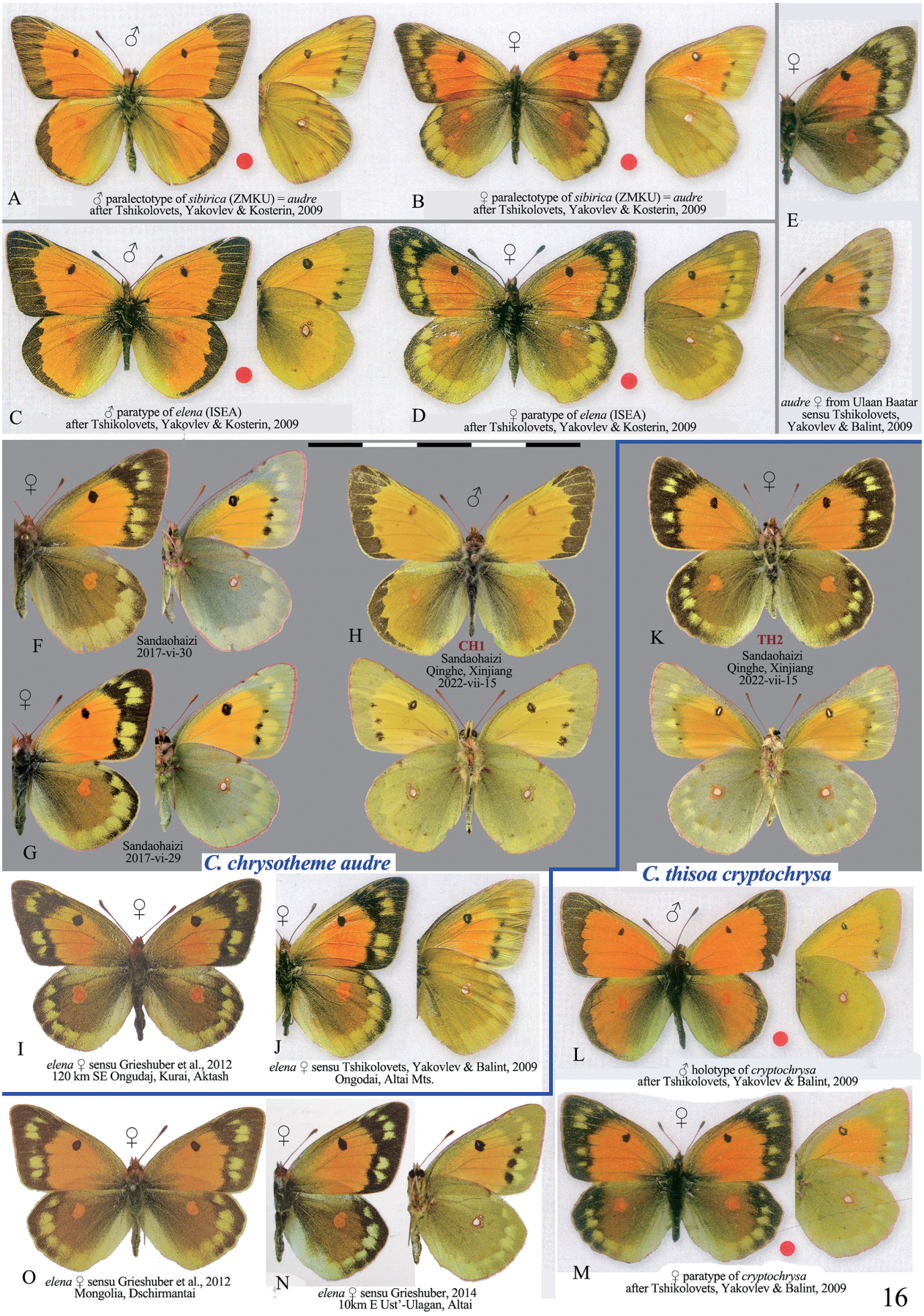

Fig. 16: Habitus of *Colias chrysotheme audre* Hemming, 1933 and *C. thisoa cryptochrysa* Yakovlev, 2006, including historical figures of specimens in literature.



Fig. 17: Habitus of *Colias thisoa* Ménétriés, 1832, ♂♂ under same scale (scale bar = 1 cm).



Fig. 18: Habitus of *Colias thisoa* Ménétriés, 1832, ♀♀ under same scale (scale bar = 1 cm).

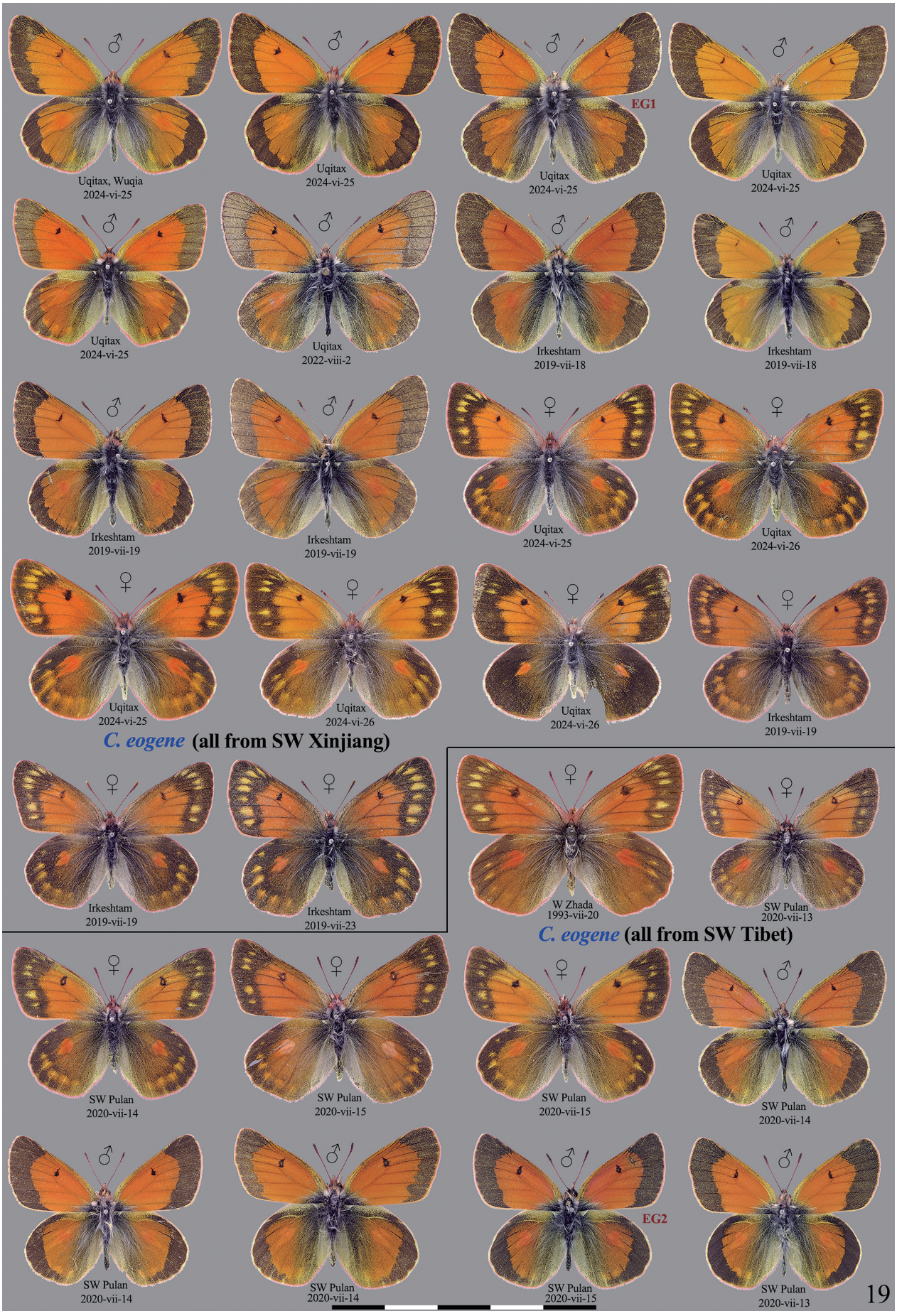

Fig. 19: Habitus of *Colias eogene* C. Felder & R. Felder, 1865 under same scale (scale bar = 1 cm): upper side.

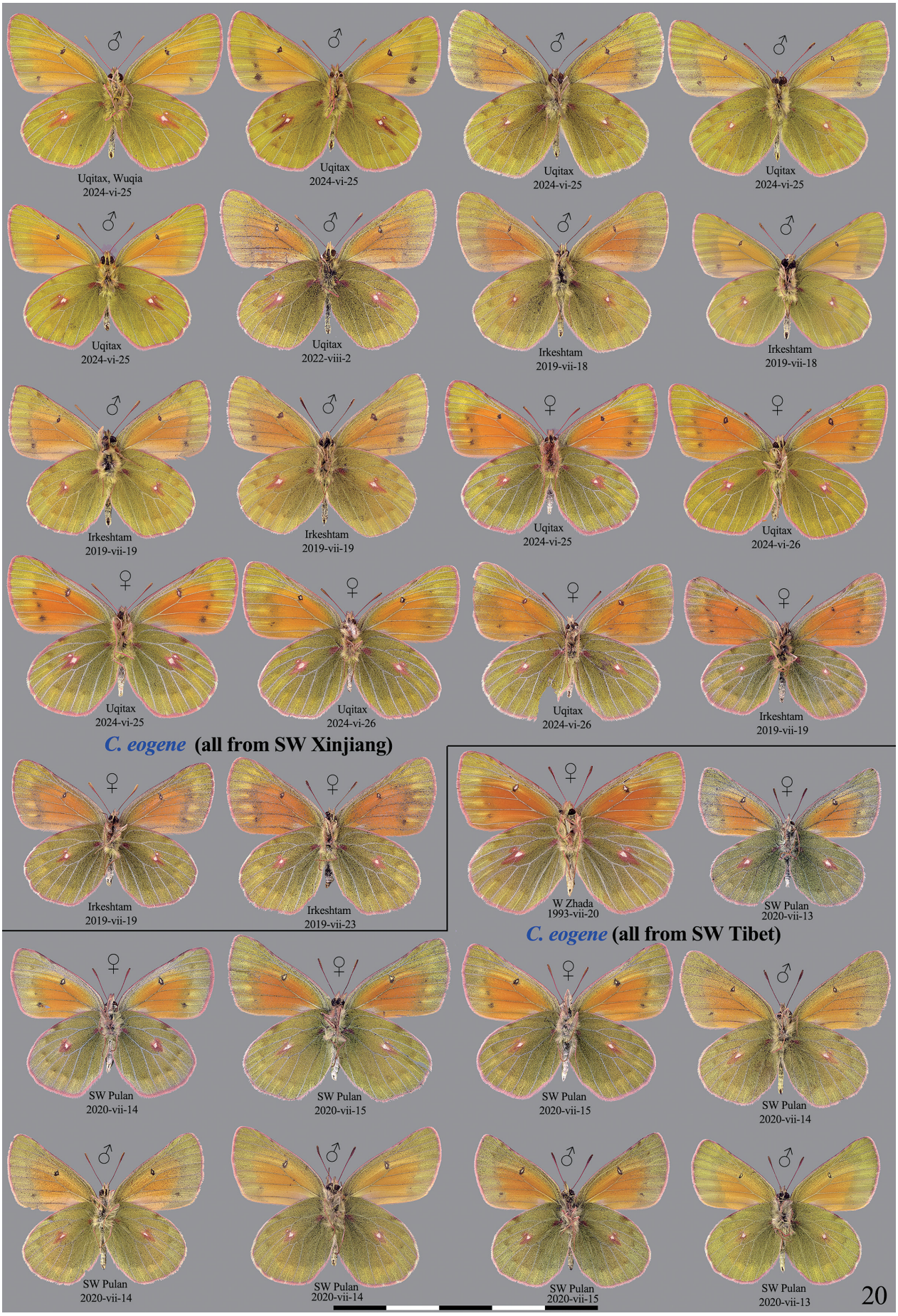

Fig. 20: Habitus of *Colias eogene* C. Felder & R. Felder, 1865 under same scale (scale bar = 1 cm): underside.



Fig. 21: Habitus of *Colias wanda* Grum-Grshimailo, 1907, *C. arida* Alphéraky, 1889, *C. stoliczkana* Moore, 1878 and *C.* ***ling*** **spec. nov.** under same scale: upper side.

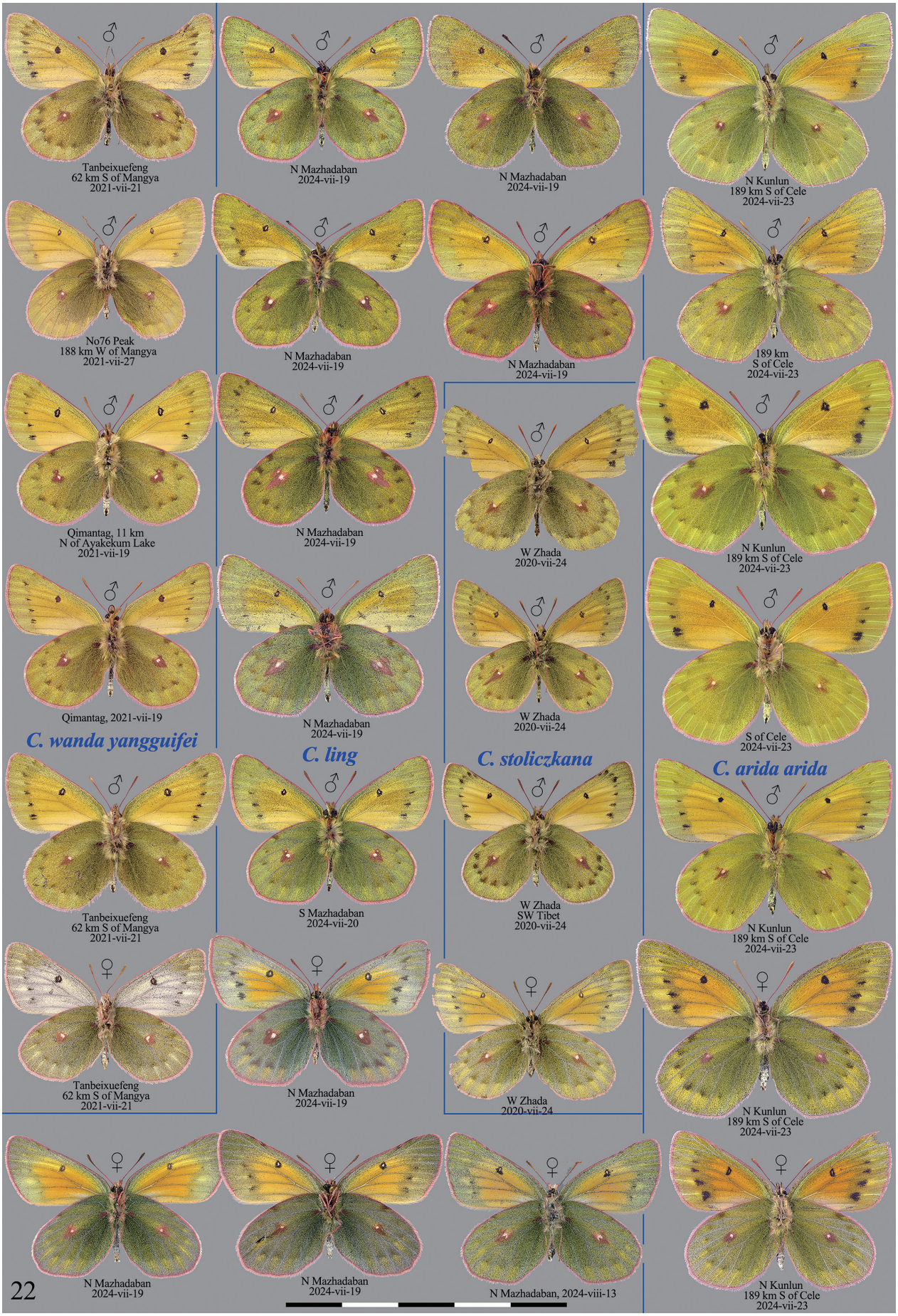

Fig. 22: Habitus of *Colias wanda* Grum-Grshimailo, 1907, *C. arida* Alphéraky, 1889, *C. stoliczkana* Moore, 1878 and *C.* ***ling*** **spec. nov.** under same scale: underside.



Fig. 23: Habitus of *Colias* ***ling*** **spec. nov.** under same scale.



Fig. 24: Single image composite showing the simultaneous dorsal (upper side) habitus of *Colias wanda* Grum-Grshimailo, 1907, *Colias stoliczkana* Moore, 1878 and *Colias* ***ling*** **spec. nov.**

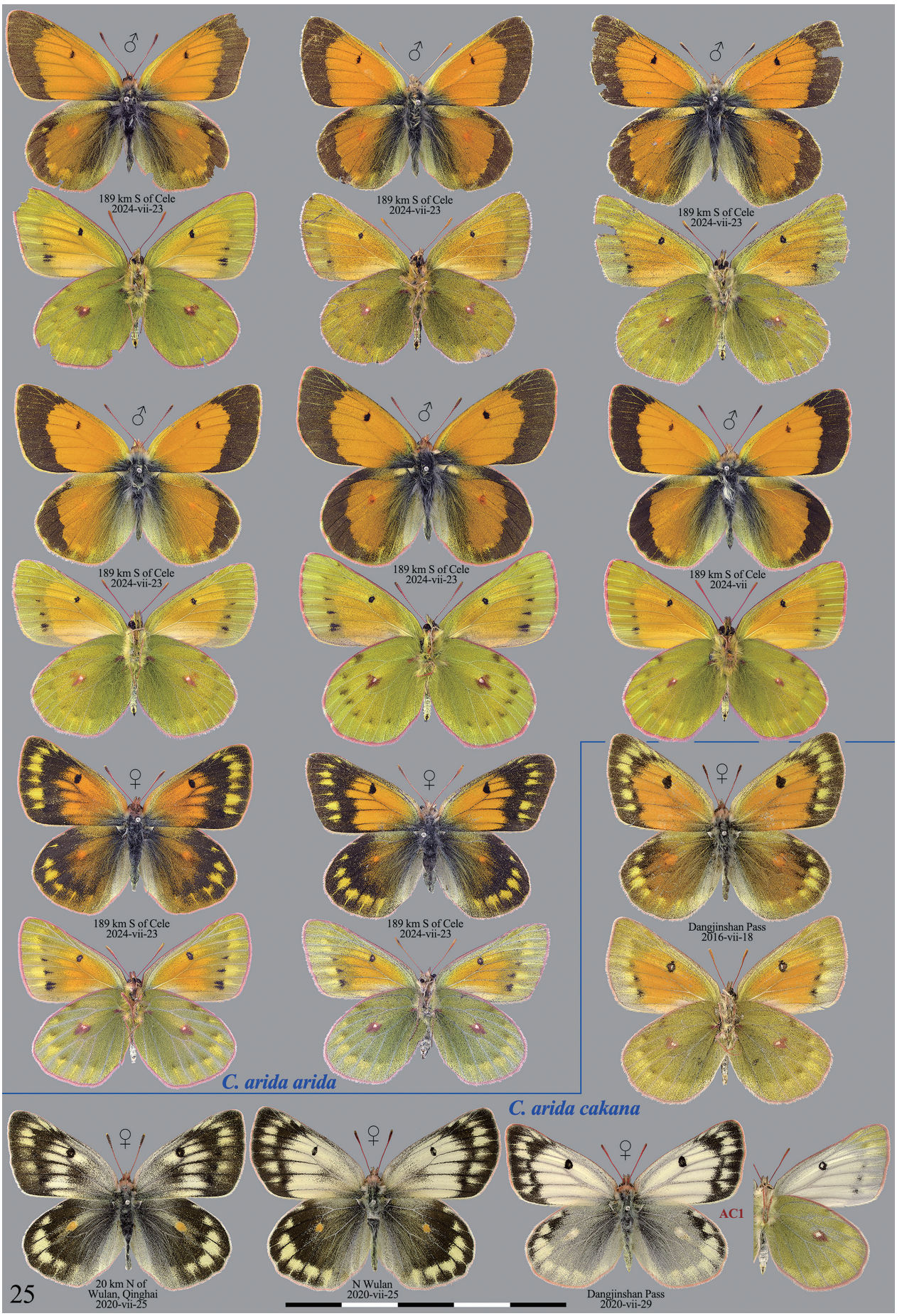

Fig. 25: Habitus of *Colias arida* Alphéraky, 1889 under same scale (scale bar = 1 cm).

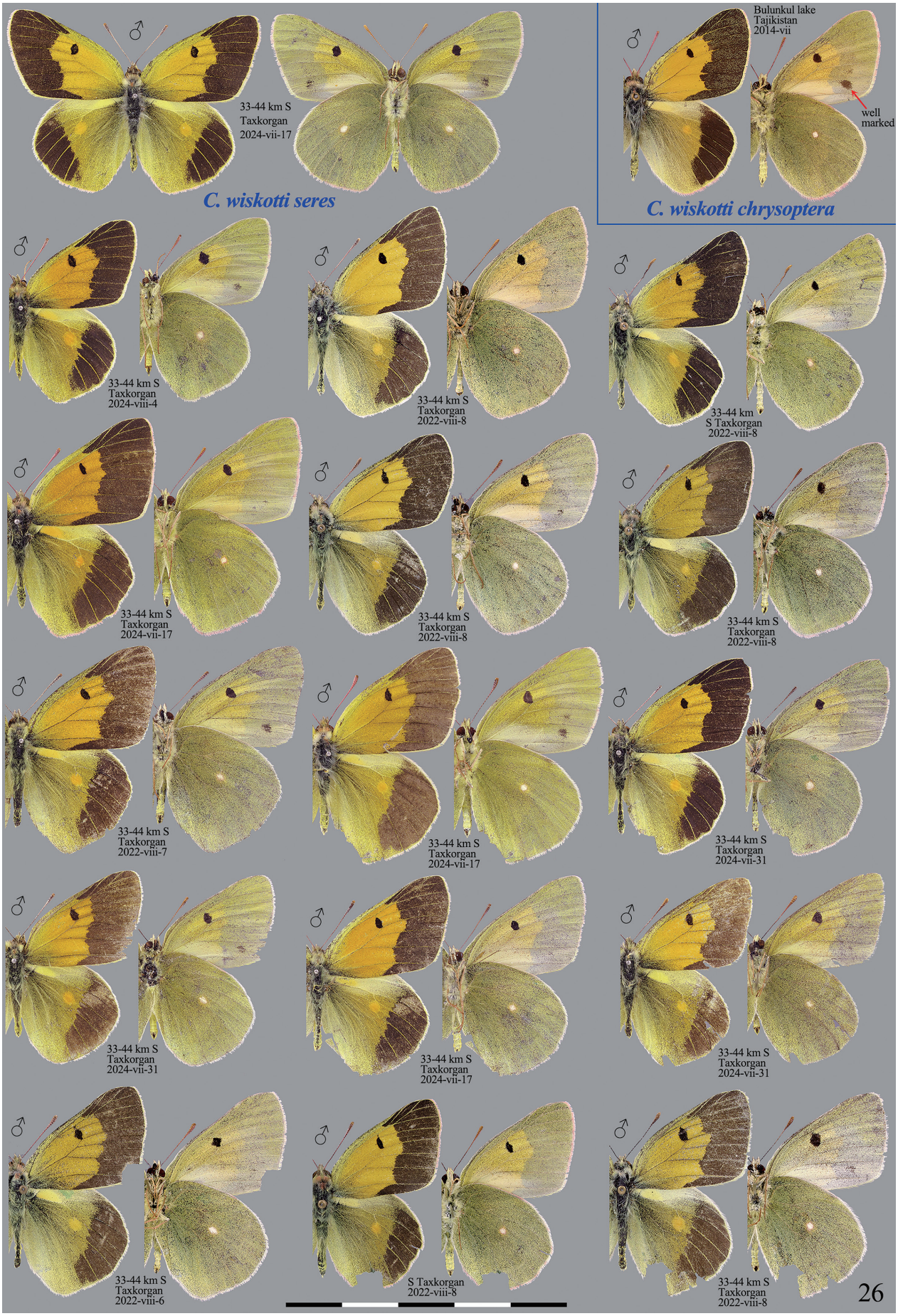

Fig. 26: Habitus of *Colias wiskotti* Staudinger, 1882 ♂♂ under same scale (scale bar = 1 cm).



Fig. 27: Habitus of *Colias wiskotti* Staudinger, 1882 ♀♀ under same scale (scale bar = 1 cm).

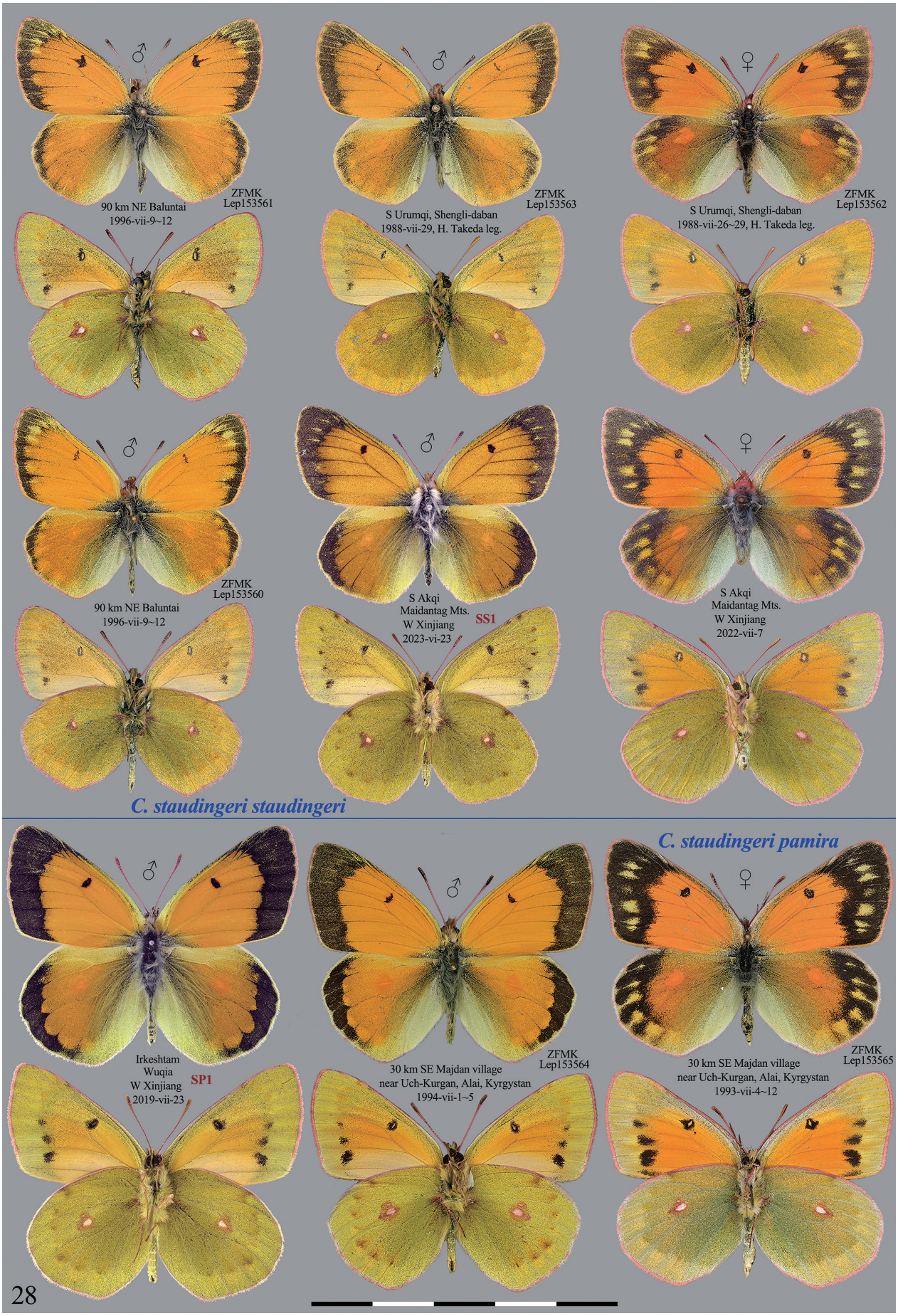

Fig. 28: Habitus of *Colias staudingeri* Alphéraky, 1881 under same scale (scale bar = 1 cm).

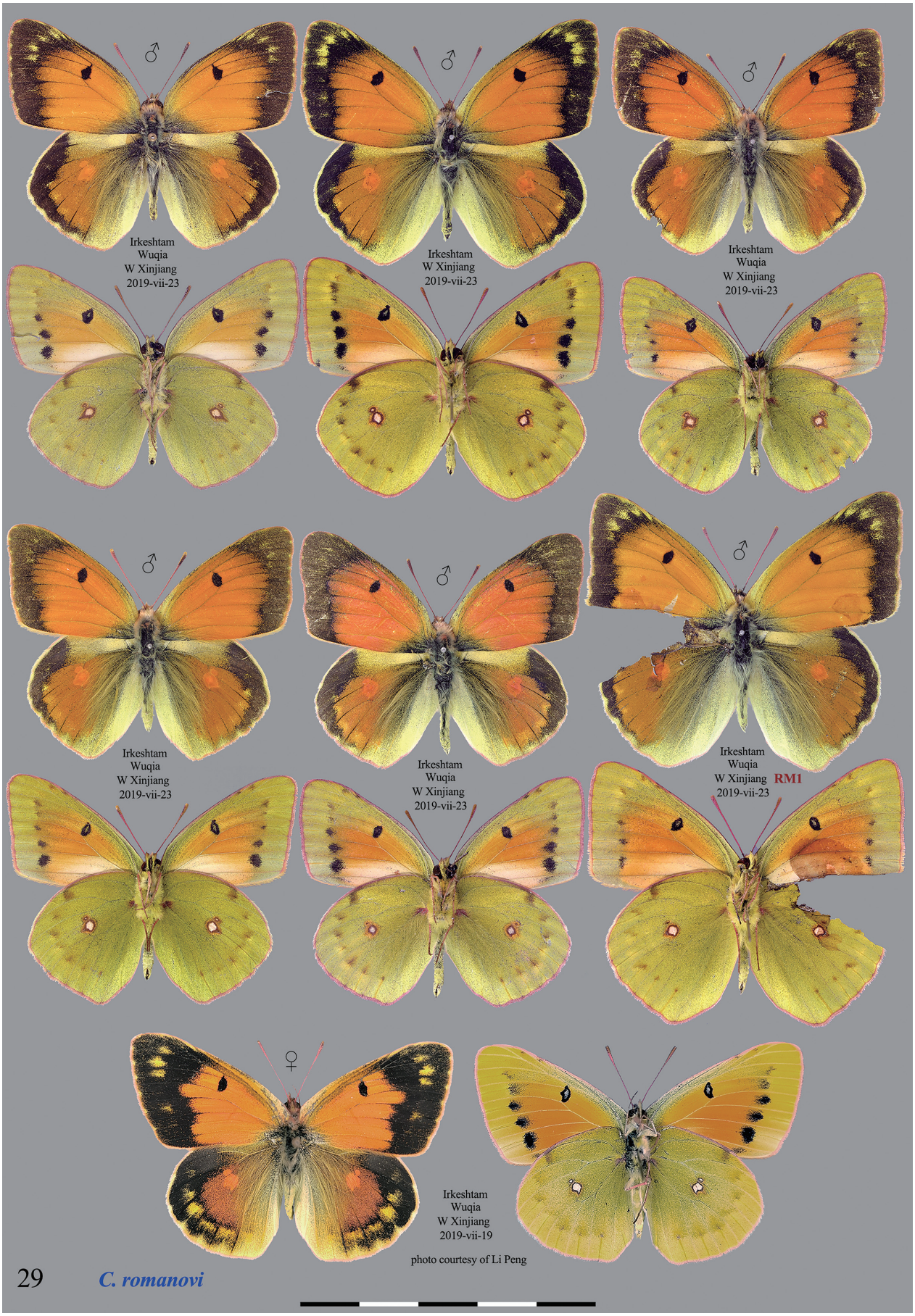

Fig. 29: Habitus of *Colias romanovi* Grum-Grshimailo, 1885 under same scale (scale bar = 1 cm).

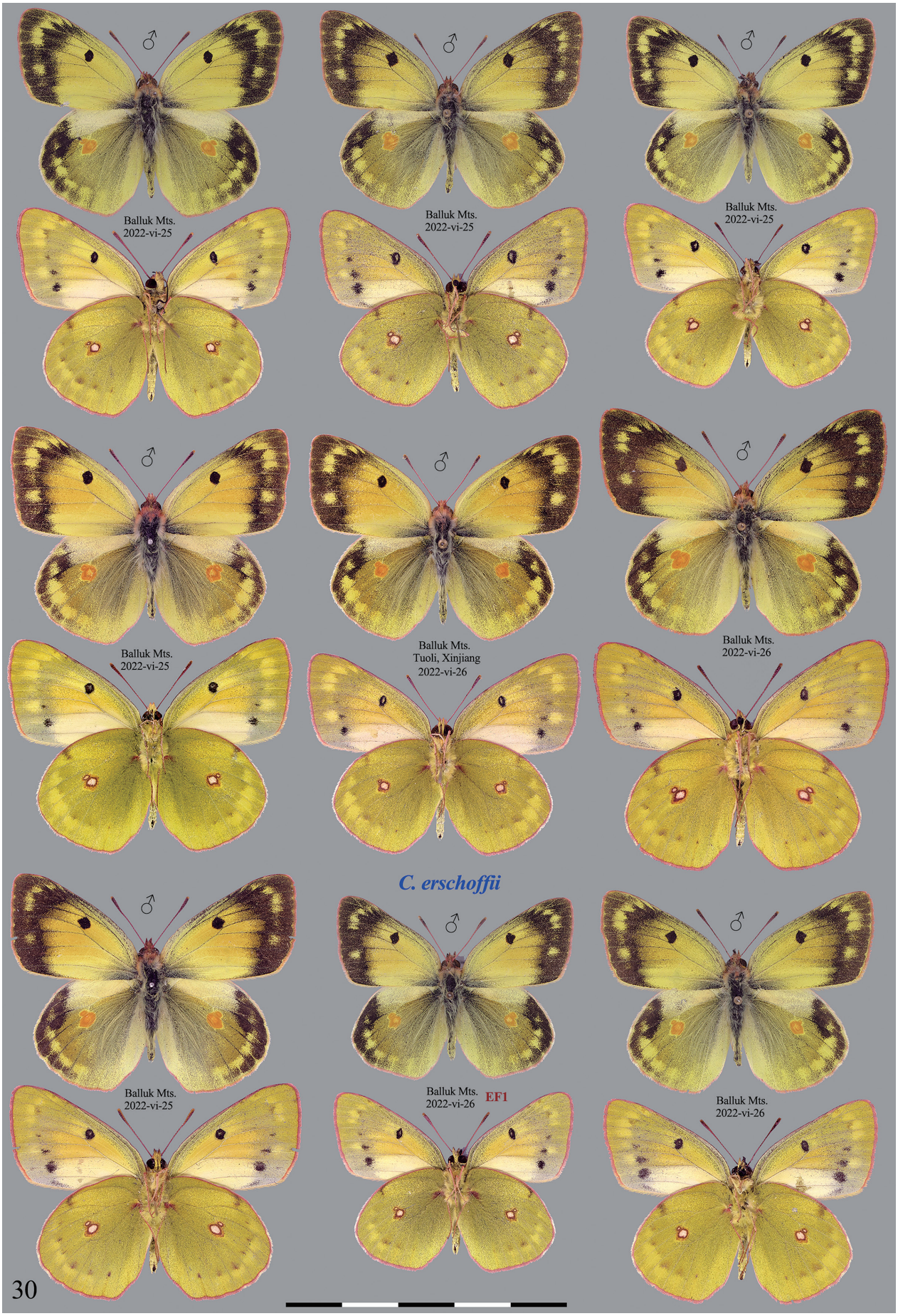

Fig. 30: Habitus of *Colias erschoffii* Alphéraky, 1881 ♂♂ under same scale (scale bar = 1 cm).

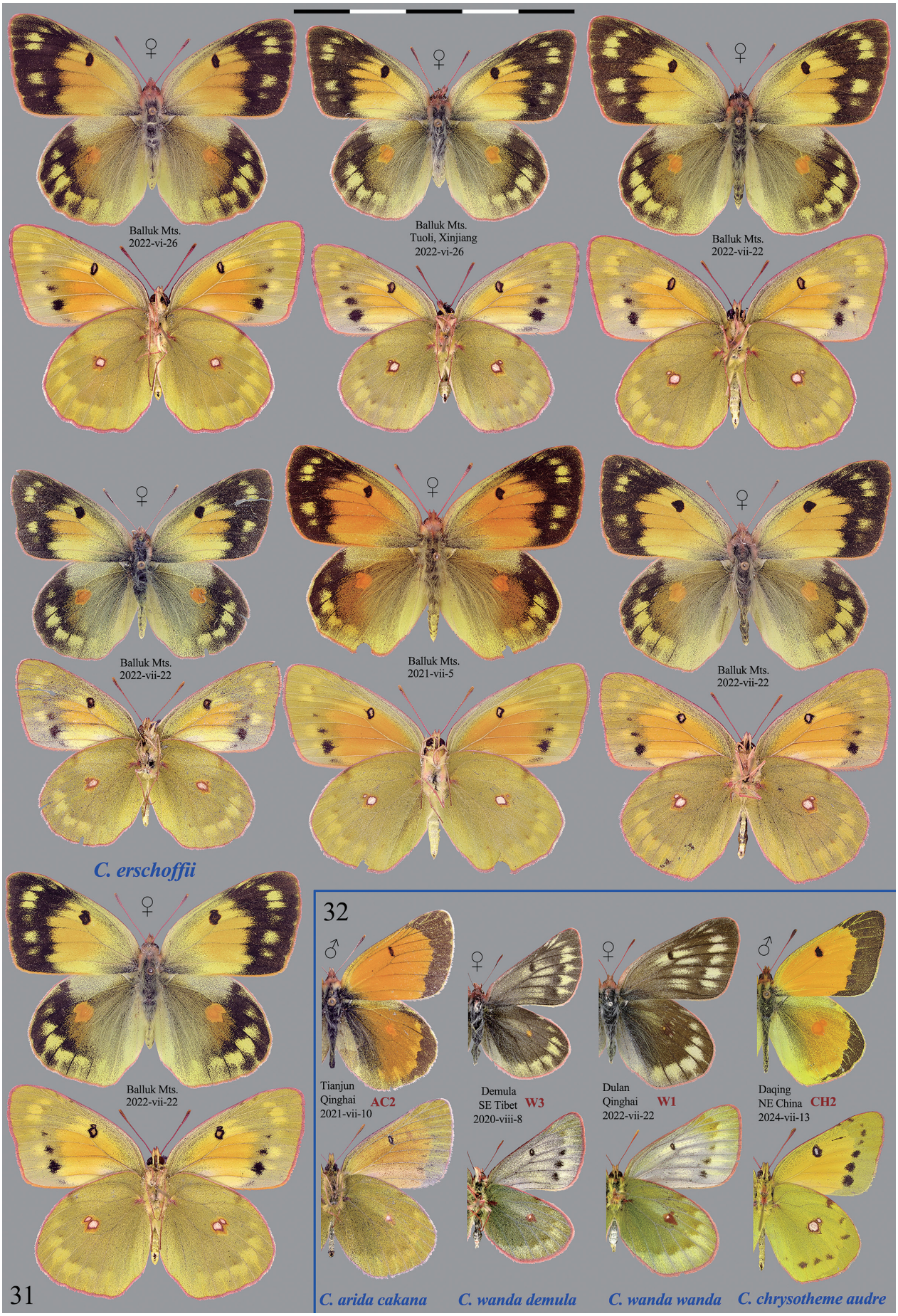

Fig. 31: Habitus of *Colias erschoffii* Alphéraky, 1881 ♀♀ under same scale (scale bar = 1 cm).
Fig. 32: Habitus of *Colias* specimens from outside Xinjiang used for molecular analysis.

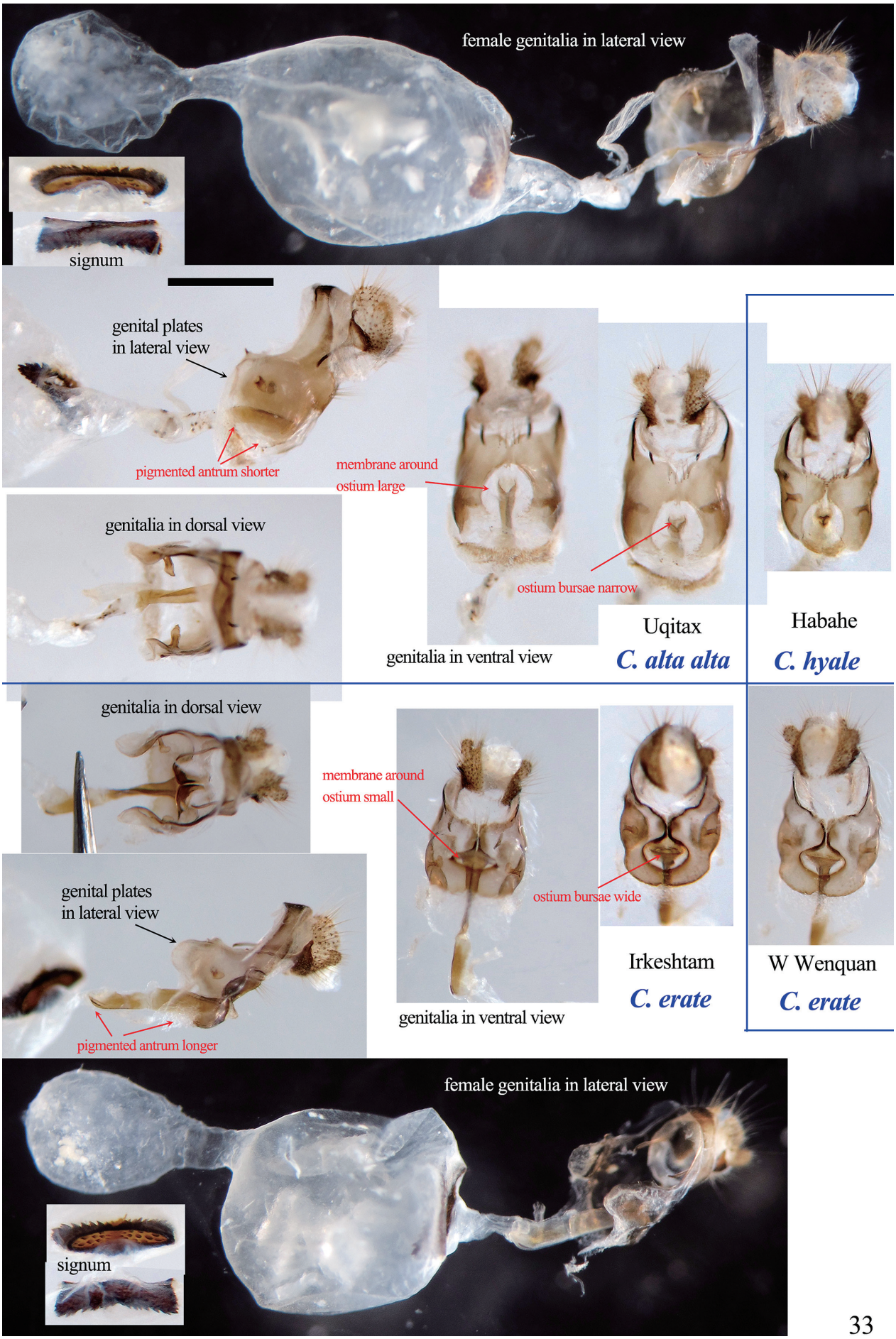

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Fig. 33: ♀ genitalia of *Colias alta* Staudinger, 1886, *C. hyale* (Linnaeus, 1758) and *C. erate* (Esper, [1805]) (scale bar = 1 mm).

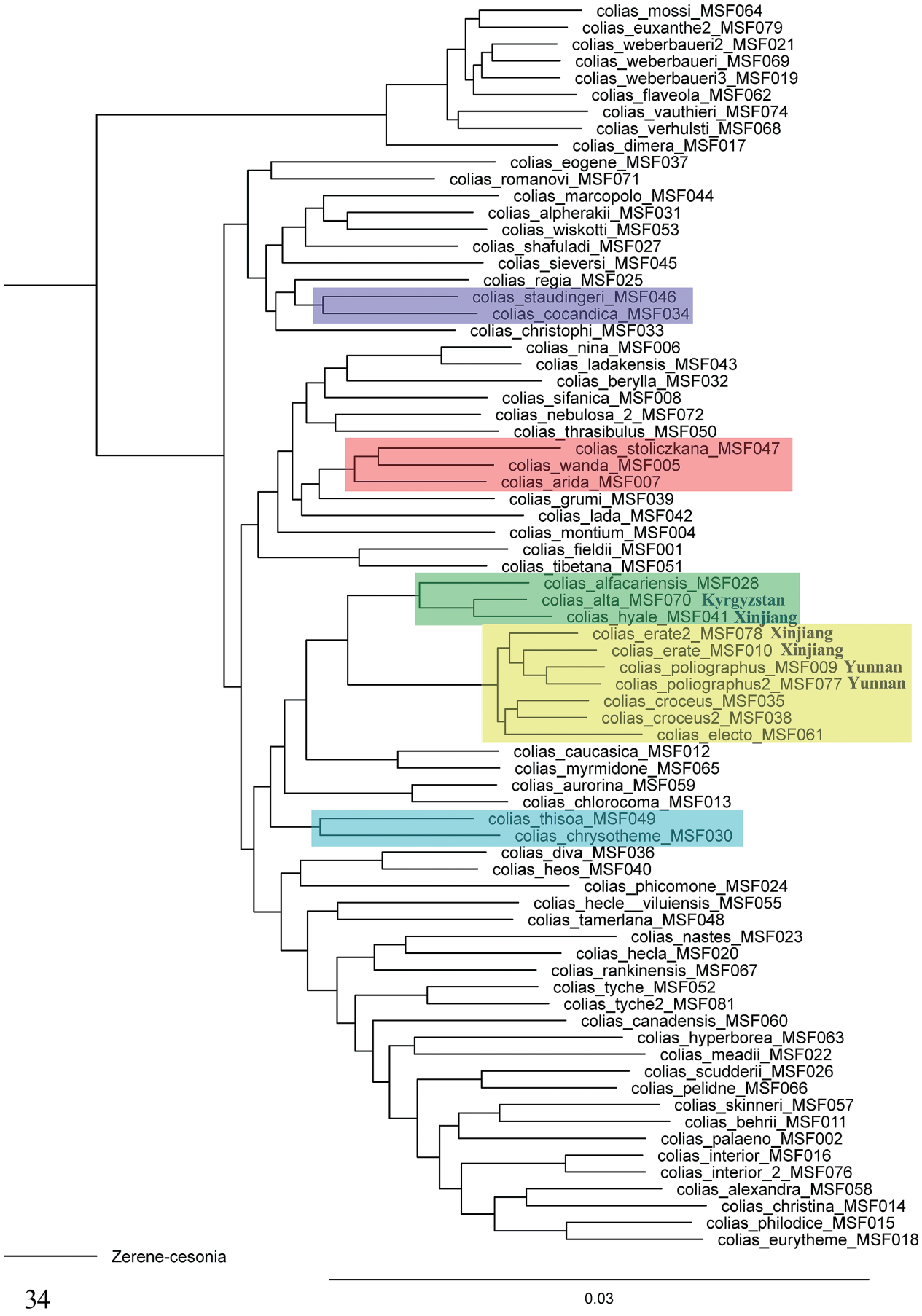

Fig. 34: nuDNA gene tree of *Colias* inferred with IQ-TREE from 150 nuclear gene loci, reproduced from Mo et al. (2025): the coloured sections corresponding to the groups treated in this work.

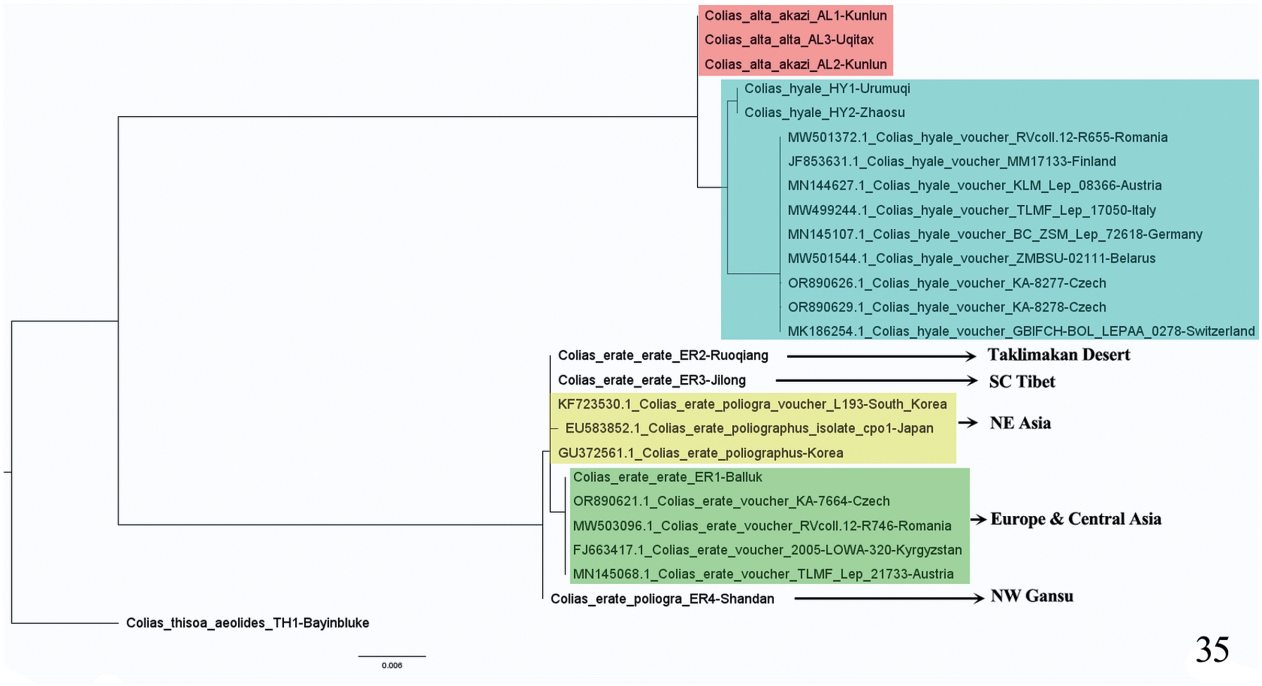

Fig. 35: mtDNA gene tree of *Colias hyale* (Linnaeus, 1758), *C. alta* Staudinger, 1886 and *C. erate* (Esper, [1805]) reconstructed by ML method using IQ-TREE based on two COI fragments (1497 bp in total).

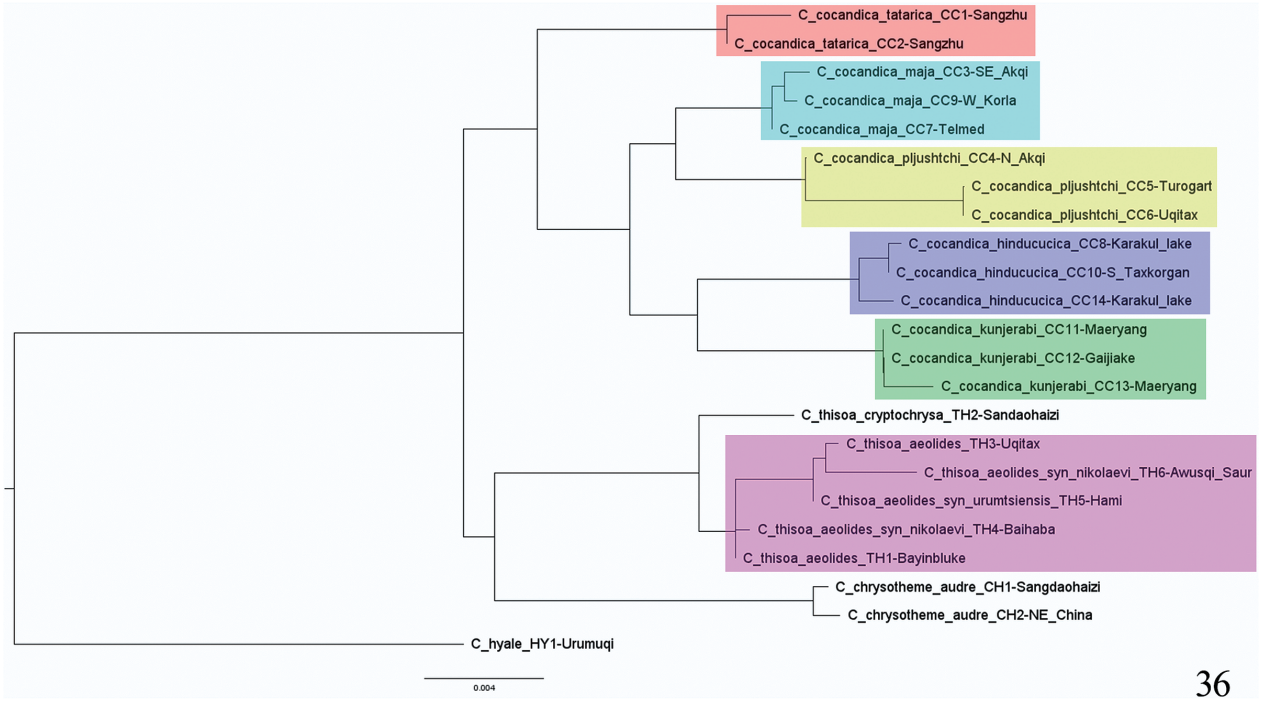

Fig. 36: Combined gene tree of *Colias cocandica* Erschoff, 1874, *C. thisoa* Ménétriés, 1832 and *C. chrysotheme* (Esper, [1781]) reconstructed by ML method using IQ-TREE based on two COI fragments (1421 bp in total) and two EF1-alpha fragments (1016 bp in total), with Auto substitution model.

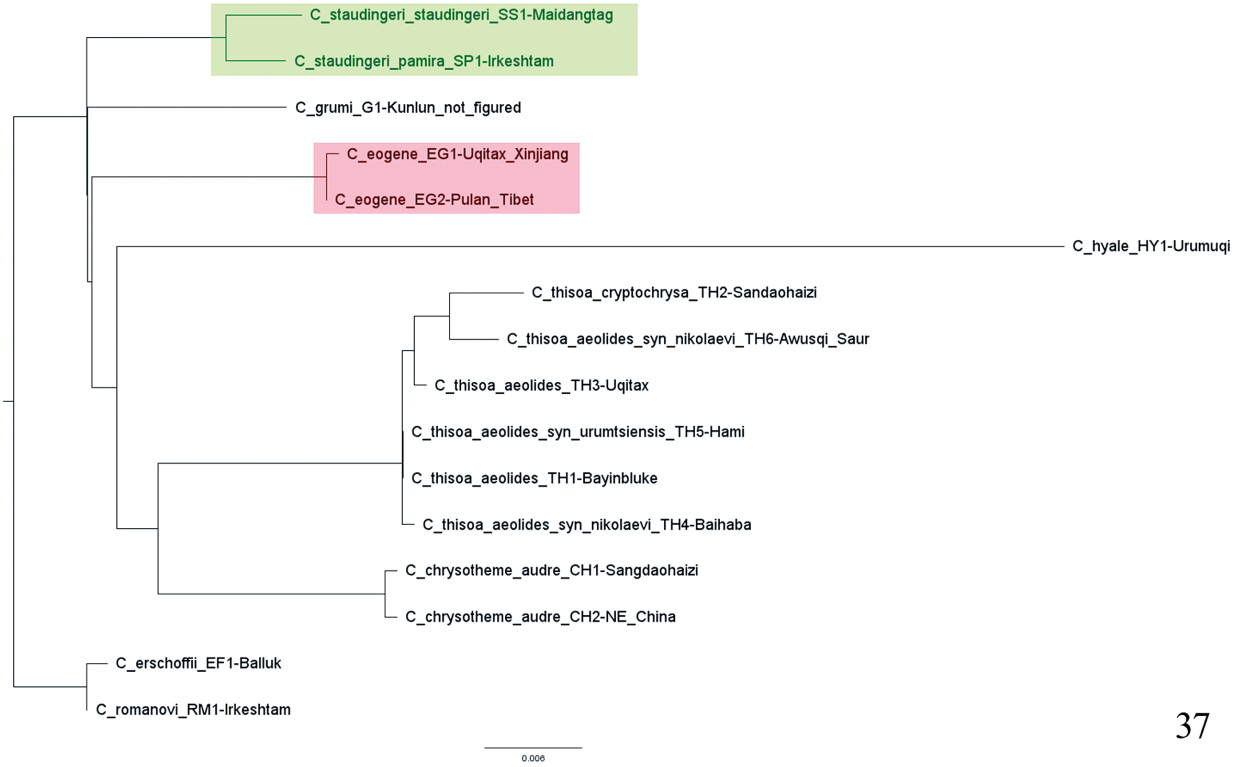

Fig. 37: mtDNA gene tree of *Colias staudingeri* Alphéraky, 1881, *C. eogene* C. Felder & R. Felder, 1865 and other Xinjiang species reconstructed by ML method using IQ-TREE based on two COI fragments (1421 bp in total).

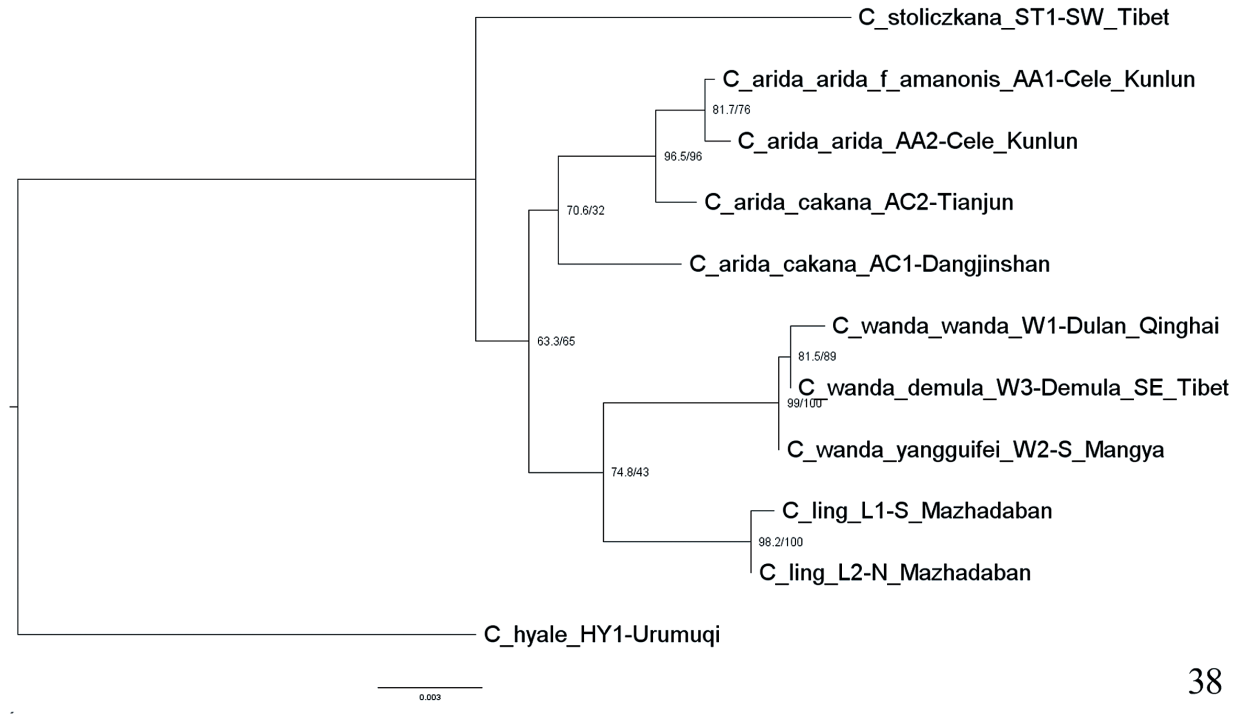

Fig. 38: Combined gene tree of *Colias stoliczkana* Moore, 1878, *C. wanda* Grum-Grshimailo, 1907, *C. arida* Alphéraky, 1889 and *C. ling* **spec. nov.** reconstructed by ML method using IQ-TREE based on two COI fragments (1421 bp in total), one Rps5 fragment (593 bp) and two EF1-alpha fragments (1016 bp in total), with Auto substitution model.

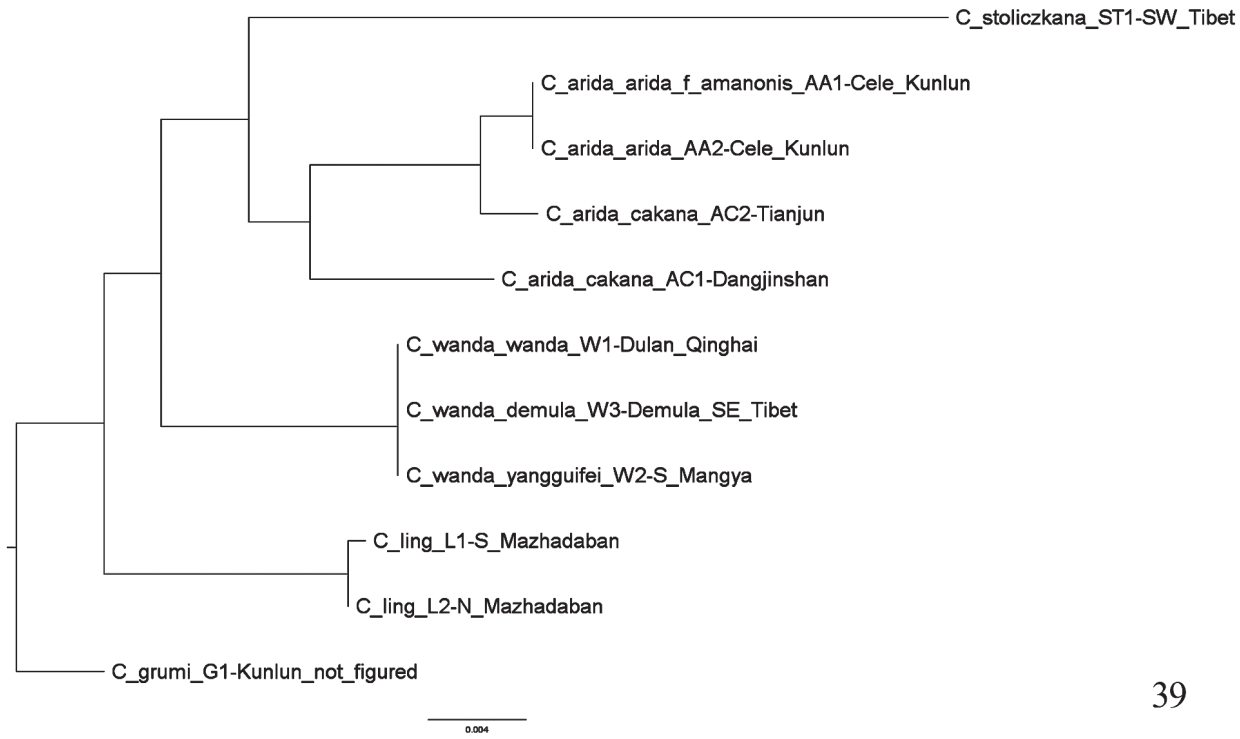

Fig. 39: mtDNA gene tree of *Colias stoliczkana* Moore, 1878, *C. wanda* Grum-Grshimailo, 1907, *C. arida* Alphéraky, 1889 and *C. ling* **spec. nov.** reconstructed by ML method using IQ-TREE based on two COI fragments (1421 bp in total).

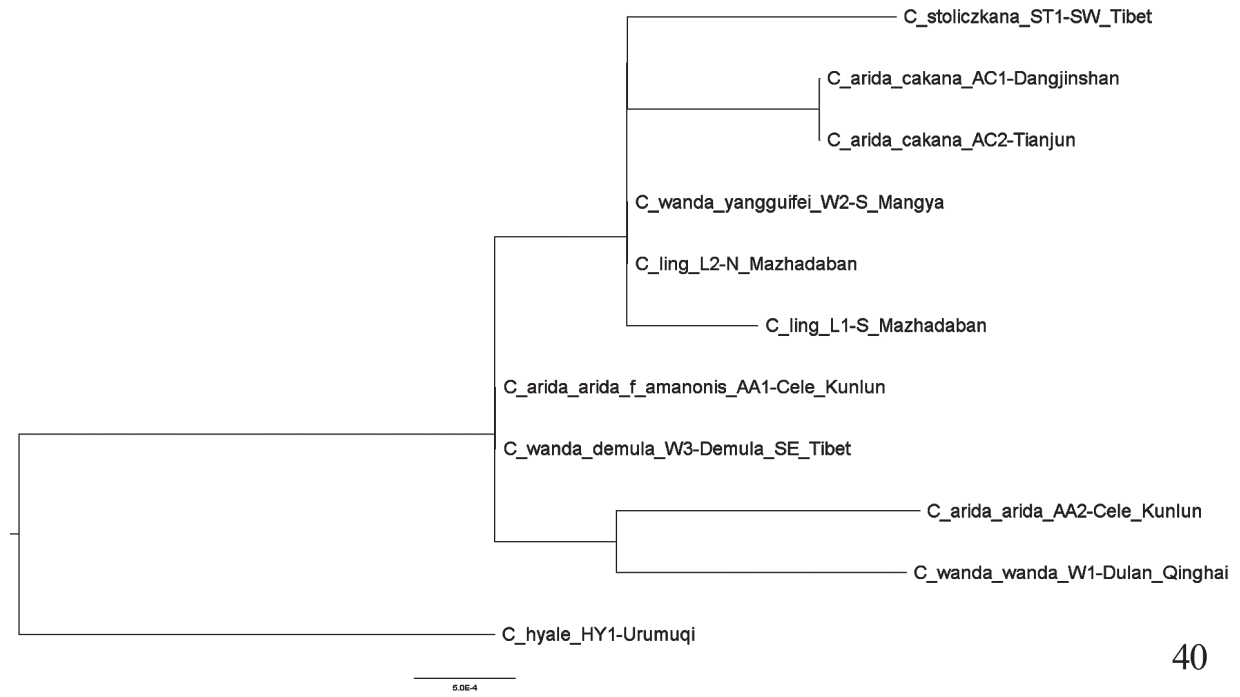

Fig. 40: nuDNA gene tree of *Colias stoliczkana* Moore, 1878, *C. wanda* Grum-Grshimailo, 1907, *C. arida* Alphéraky, 1889 and *C. ling* **spec. nov.** reconstructed by ML method using IQ-TREE based on one Rps5 fragment (593 bp) and two EF1-alpha fragments (1016 bp in total), with Auto substitution model.

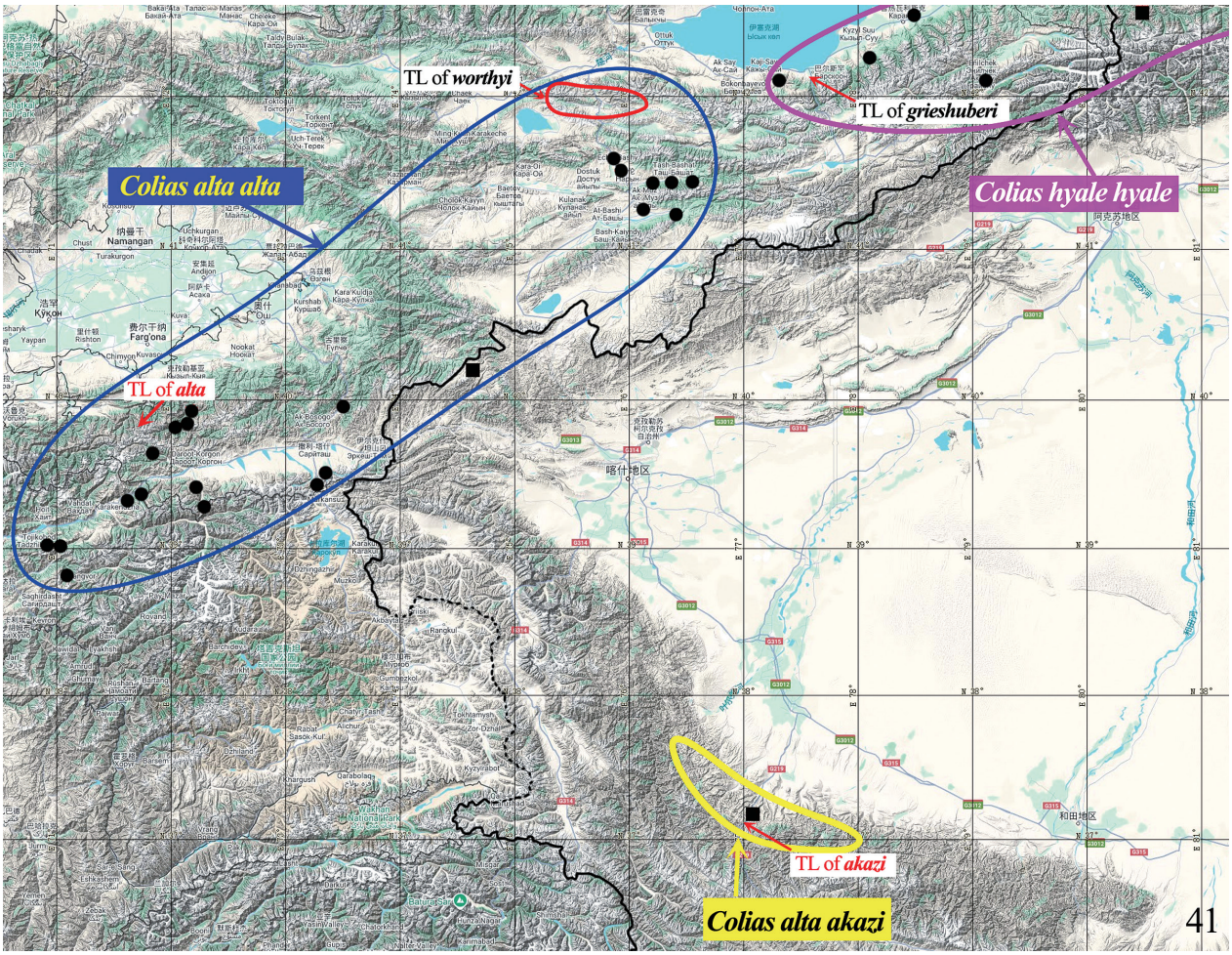

Fig. 41: Distribution of *Colias hyale* (Linnaeus, 1758) and *C. alta* Staudinger, 1886 [Localities marked by black circles outside China are transcribed from Tshikolovets (2003, 2005b); black squares indicate records from this study.].

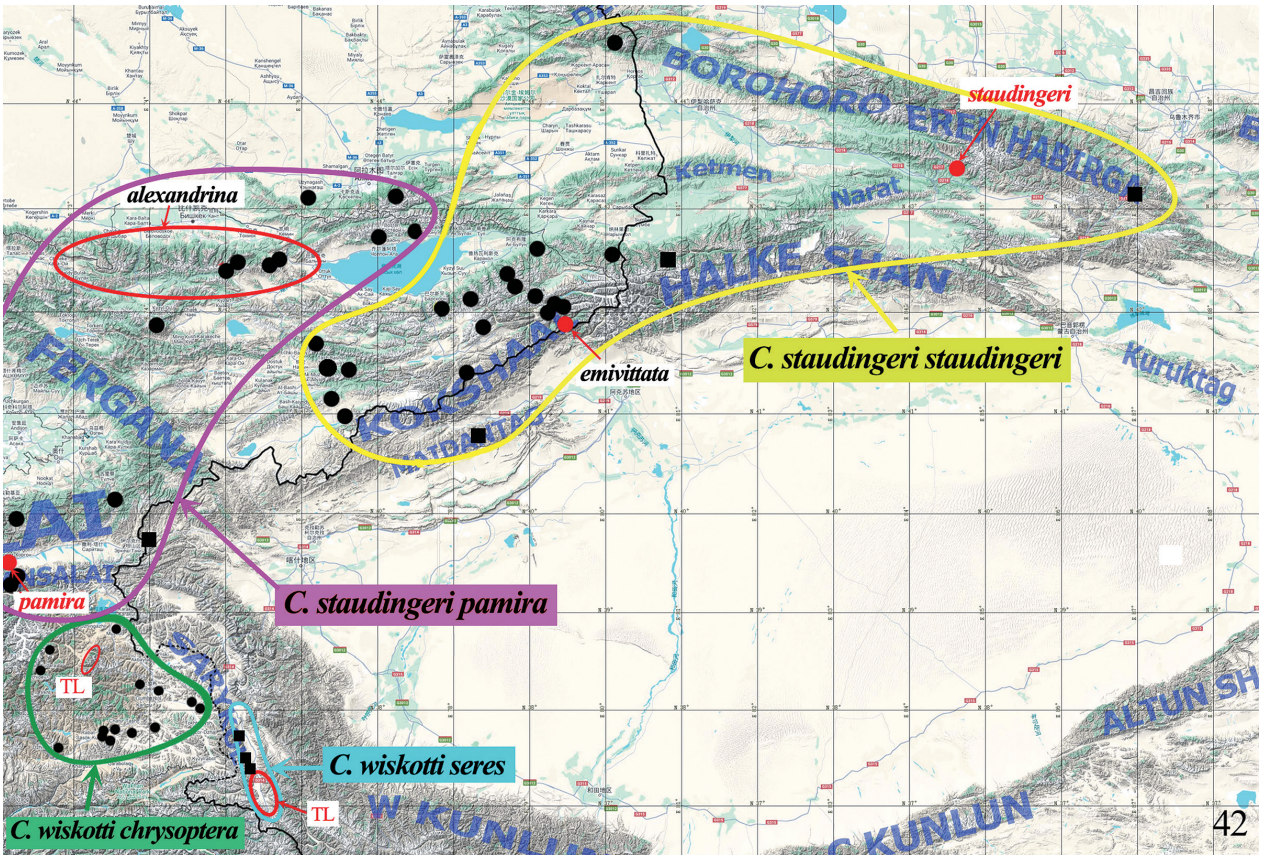

Fig. 42: Distribution of *Colias staudingeri* Alphéraky, 1881 and *C. wiskotti* Staudinger, 1882 [Localities marked by black circles outside China are transcribed from Tshikolovets (2003, 2005b) and Tshikolovets et al. (2016)].

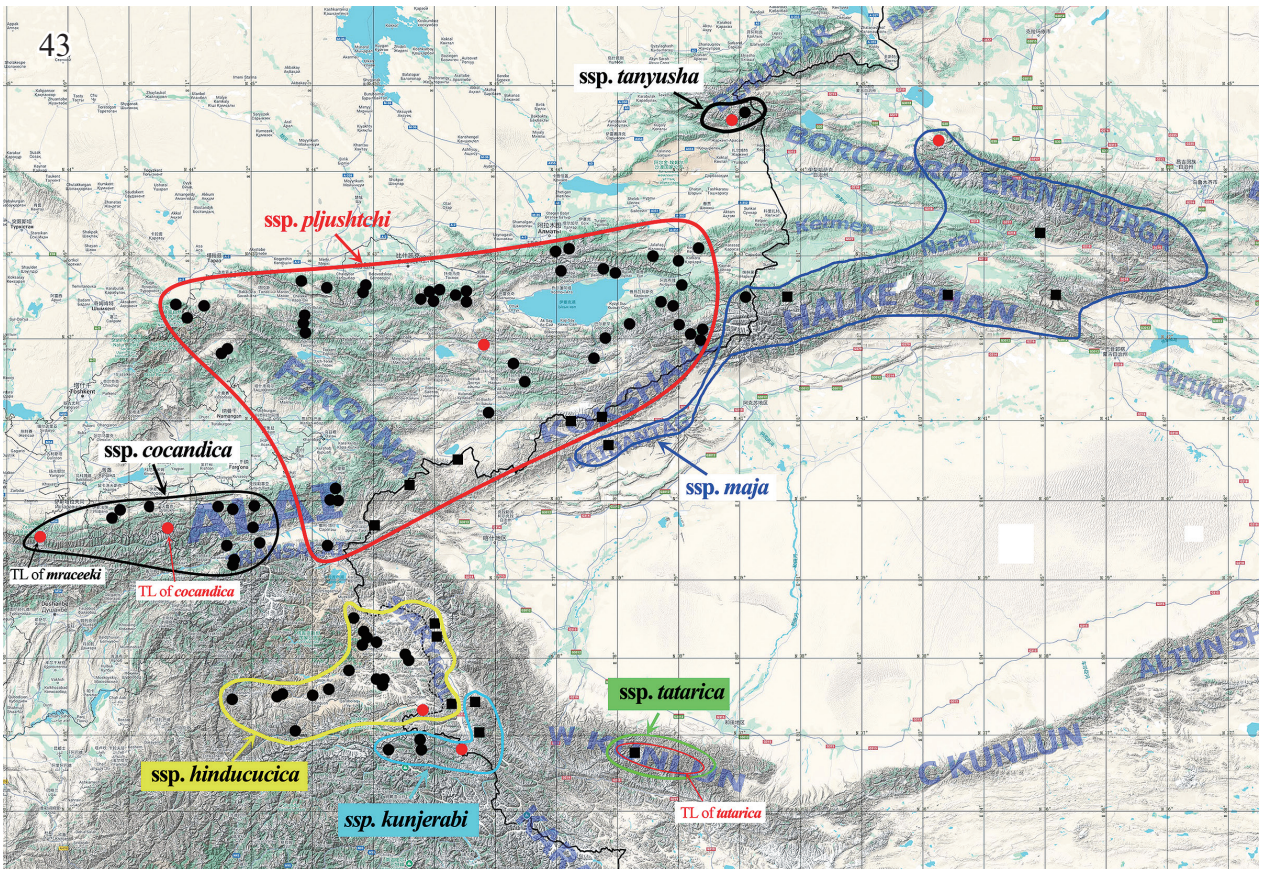

Fig. 43: Distribution of *Colias cocandica* Erschoff, 1874 [Localities marked by black circles outside China are transcribed from Tshikolovets (2003, 2005b) and Tshikolovets & Pages (2016); black squares indicate records from this study; red circles indicate TLs.]

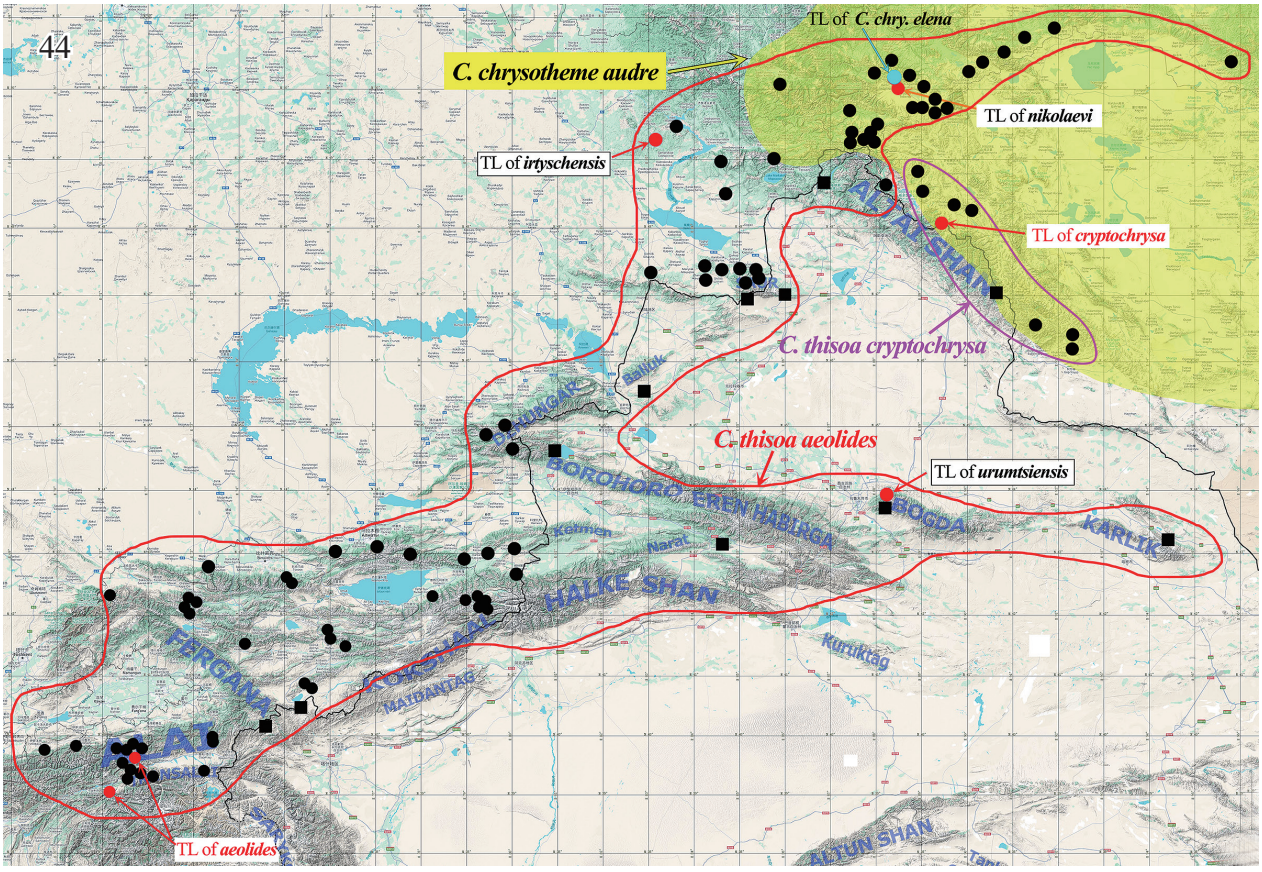

Fig. 44: Distribution of *Colias thisoa* Ménétriés, 1832 and *C. chrysotheme audre* Hemming, 1933 (range indicated by yellow colouring instead of black dots) [Localities marked by black circles outside China are transcribed from Tshikolovets (2005b) and Tshikolovets et al. (2009a, 2009b, 2016); black squares indicate records from this study; red circles indicate TLs.]

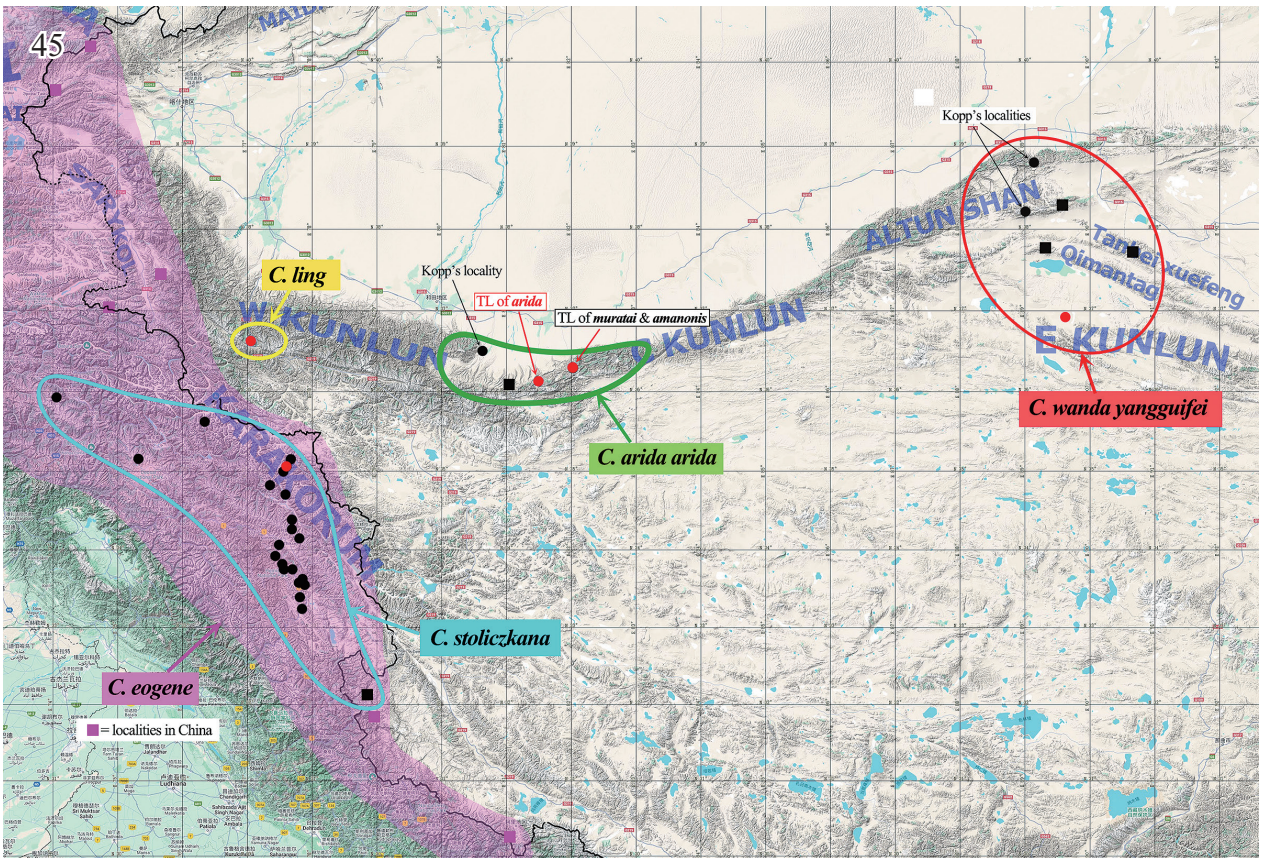

Fig. 45: Distribution of *Colias eogene* C. Felder & R. Felder, 1865 (range indicated by pink colouring and pink squares), *C. arida arida* Alphéraky, 1889, *C. wanda yangguifei* R.-X. Huang & Murayama, 1992, *C. stoliczkana* Moore, 1878 and *C. ling* **spec. nov.** [Localities marked by black circles outside China are transcribed from Tshikolovets (2005a) and Tshikolovets & Pages (2016); black squares indicate records from this study; red circles indicate TLs.]







Figs. 46-48: Biotopes: 46- *Colias ling* **spec. nov.** at Mazha daban; 47- *C. alta akazi* **subspec. nov.** at north of Akazi daban; 48- *C. arida arida* Alphéraky, 1889 at south of Cele, C Kunlun Mts.





Figs. 49-50: Biotopes: 49- *Colias chrysotheme audre* Hemming, 1933 and *C. thisoa cryptochrysa* Yakovlev, 2006 at Sandaohaizi; 50- *C. romanovi* Grum-Grshimailo, 1885 at Irkeshtam.



Figs. 51-56: Biotopes: 51- *Colias erschoffii* Alphéraky, 1881 at Balluk Mts.; 52- *C. cocandica hinducucica* Tytler, 1926 at Torugart; 53- *C. thisoa aeolides* Grum-Grshimailo, 1890, *C. eogene* C. Felder & R. Felder, 1865 and *C. alta alta* Staudinger, 1886 at Uqitax; 54- *C. romanovi* Grum-Grshimailo, 1885 and *C. staudingeri pamira* Grum-Grshimailo, 1890 at Irkeshtam; 55- *C. tamerlana* Staudinger, 1897 at Sandaohaizi; 56- *C. wiskotti seres* Grum-Grshimailo, 1890 at a valley of Sarykol Mts.