

Introduction to Focus Stacking

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You Don't Need to Take Notes

These slides are available online.

See the “Tutorials” section at
<http://zerenestacker.com>

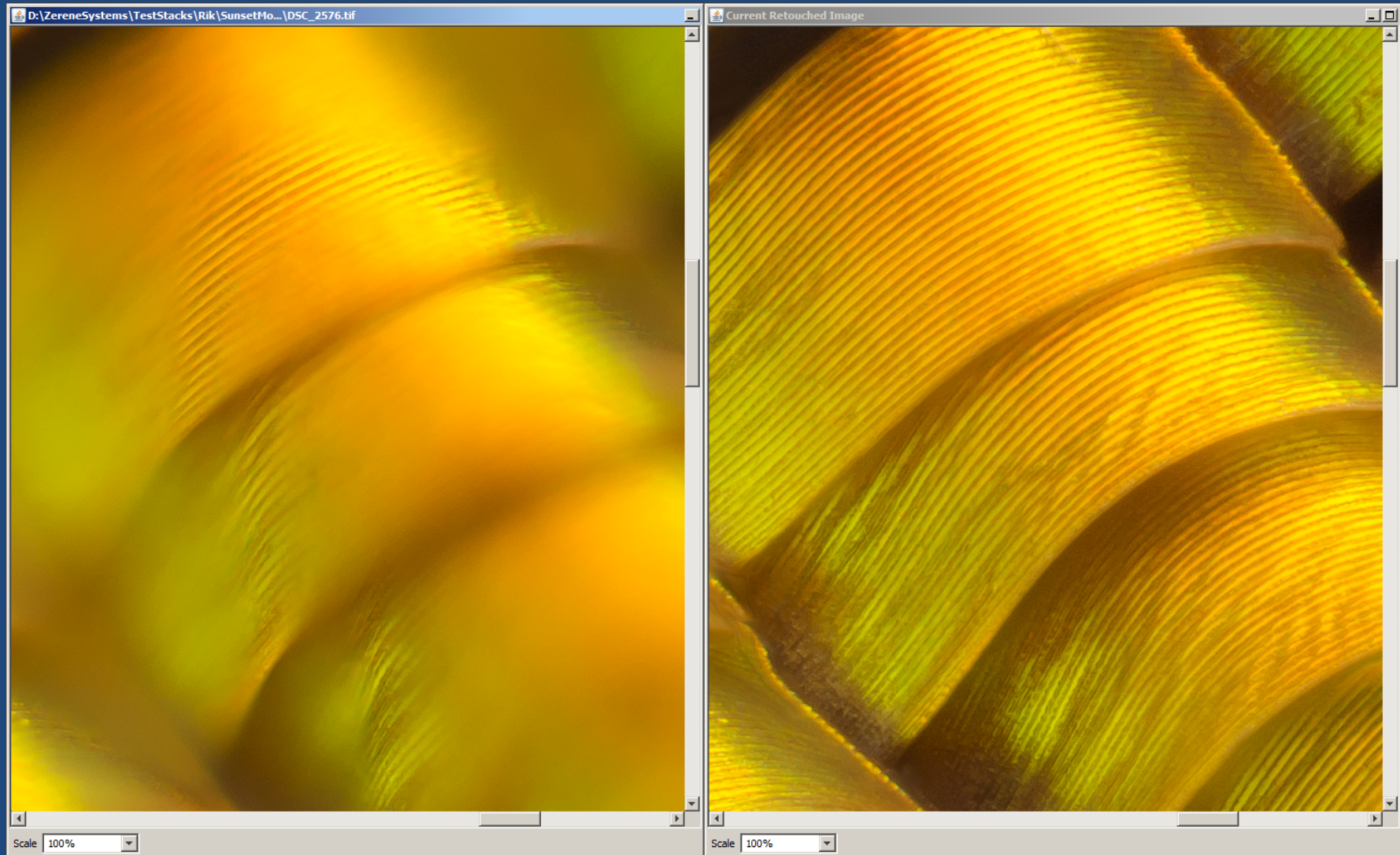
The handout lists other references.

I Like Focus Stacking For Small Things

Wing scales of a Sunset Moth -- frame width here about 0.1 mm

Single Frame

Stacked, focus step 0.002 mm



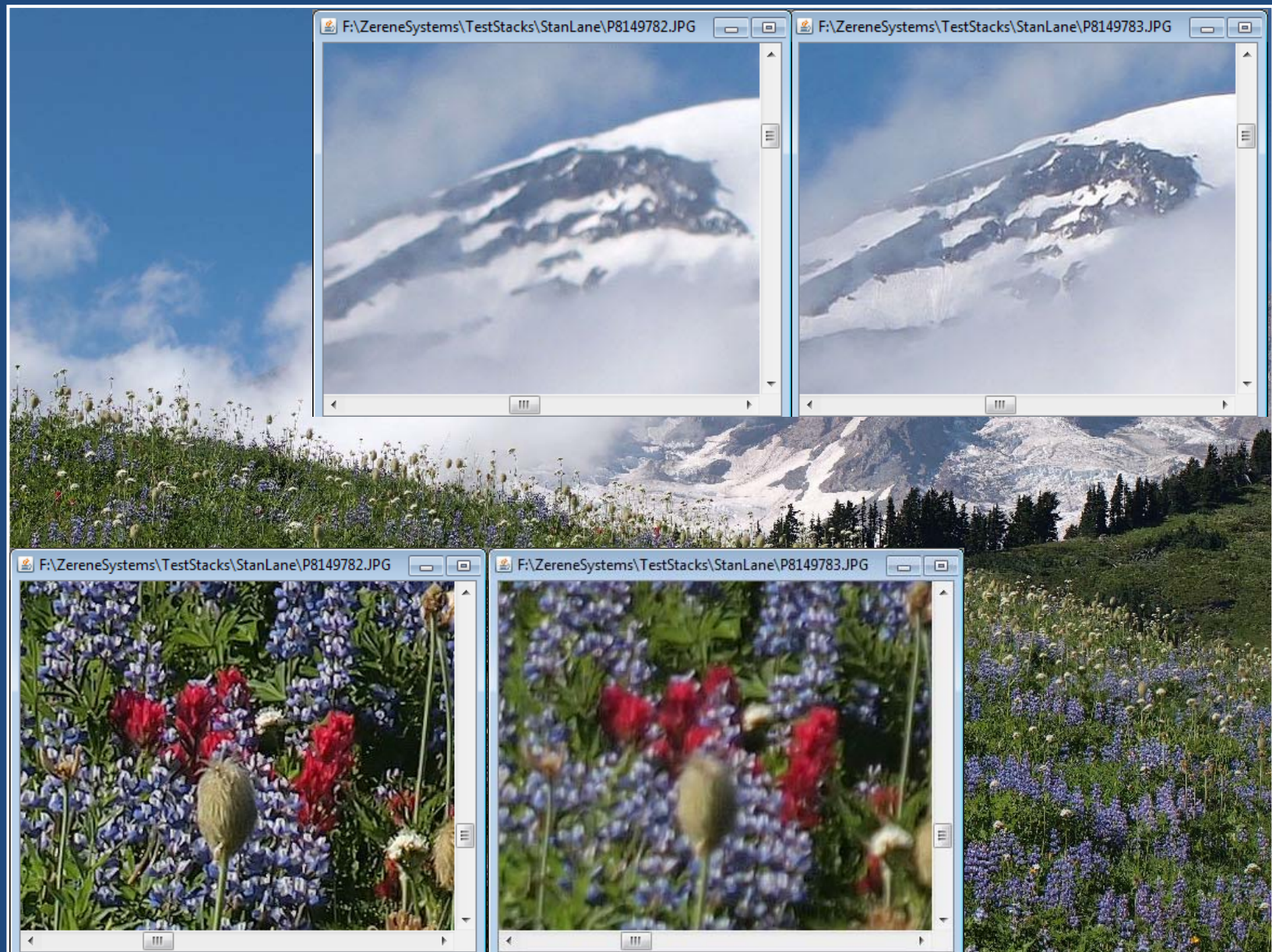
But It's Handy for Big Subjects Too

(Mt. Rainier, assembled from 3 Frames)



Image by Stan Lane

Why Focus Stack Mt. Rainier?



Mt. Rainier, Sharp Everywhere



“Focus Stacking”

Why: Get more depth of field, sharper subjects, smoother backgrounds

How:

Step 1) Shoot multiple images, changing focus.

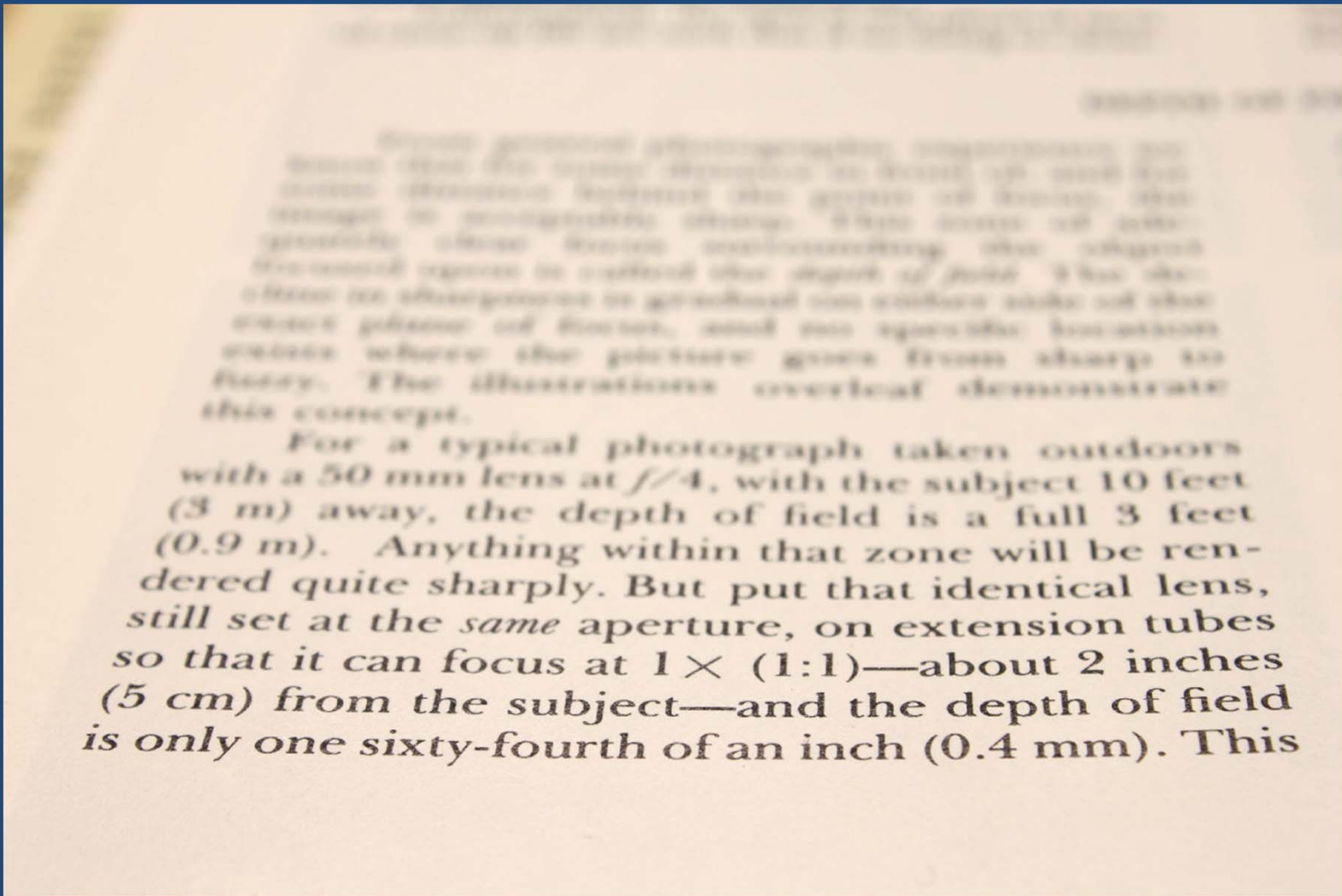
Step 2) Run this “stack” of images through a computer to pick out the sharp bits.

Static subjects only – plan ahead.

A Simple Example... Here's the Scene



As Seen by the Camera (f/8)

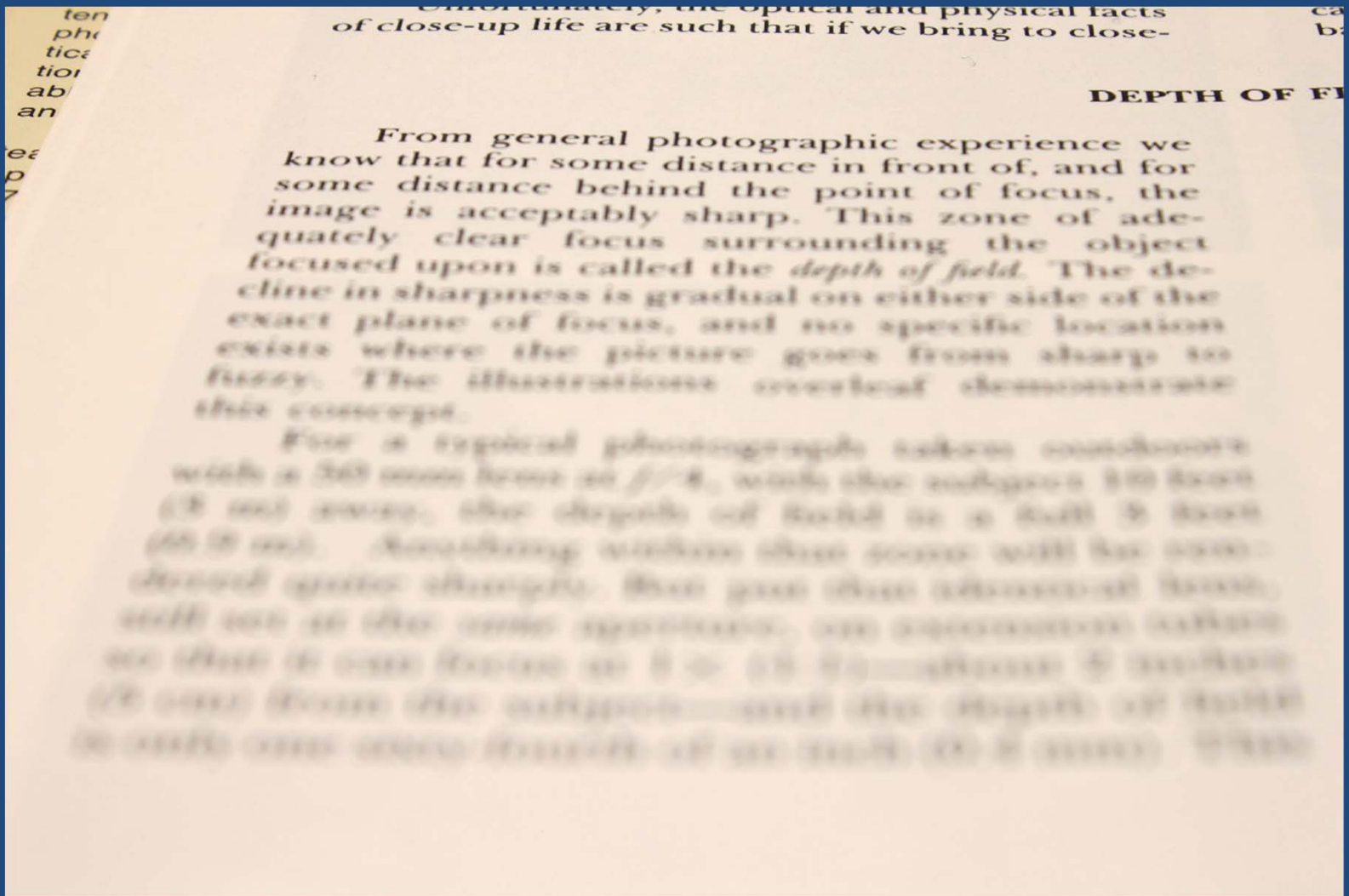


As Seen by the Camera (f/8)

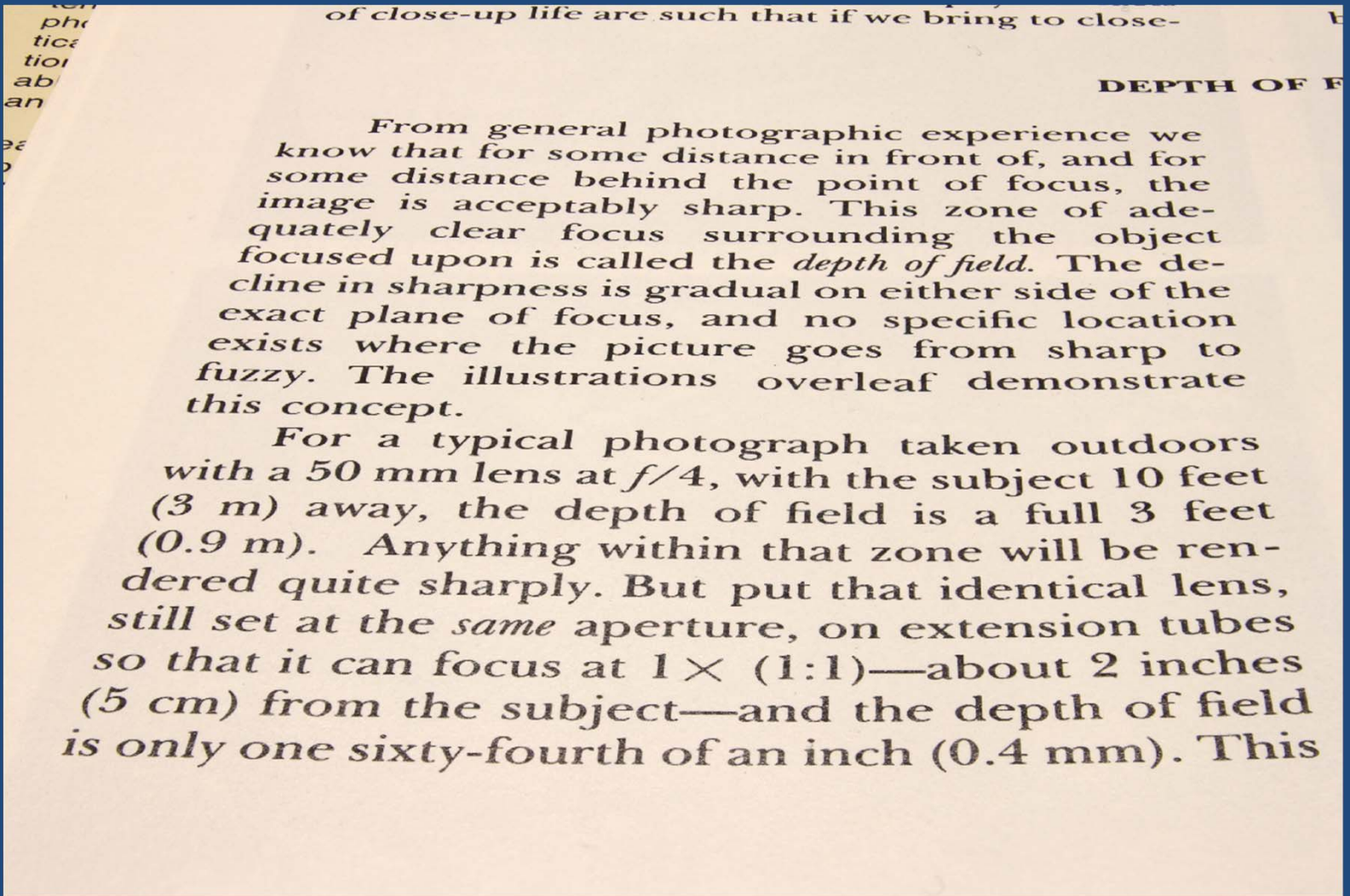
From general photographic experience we know that for some distance in front of, and for some distance behind the point of focus, the image is acceptably sharp. This zone of adequately clear focus surrounding the object focused upon is called the *depth of field*. The decline in sharpness is gradual on either side of the exact plane of focus, and no specific location exists where the picture goes from sharp to fuzzy. The illustrations overleaf demonstrate this concept.

For a typical photograph taken outdoors with a 50 mm lens at $f/4$, with the subject 10 feet (3 m) away, the depth of field is a full 3 feet (0.9 m). Anything within that zone will be rendered quite sharply. But put that identical lens, still set at the *same* aperture, on extension tubes so that it can focus at $1\times$ (1:1)—about 2 inches (5 cm) from the subject—and the depth of field is only one sixty-fourth of an inch (0.4 mm). This

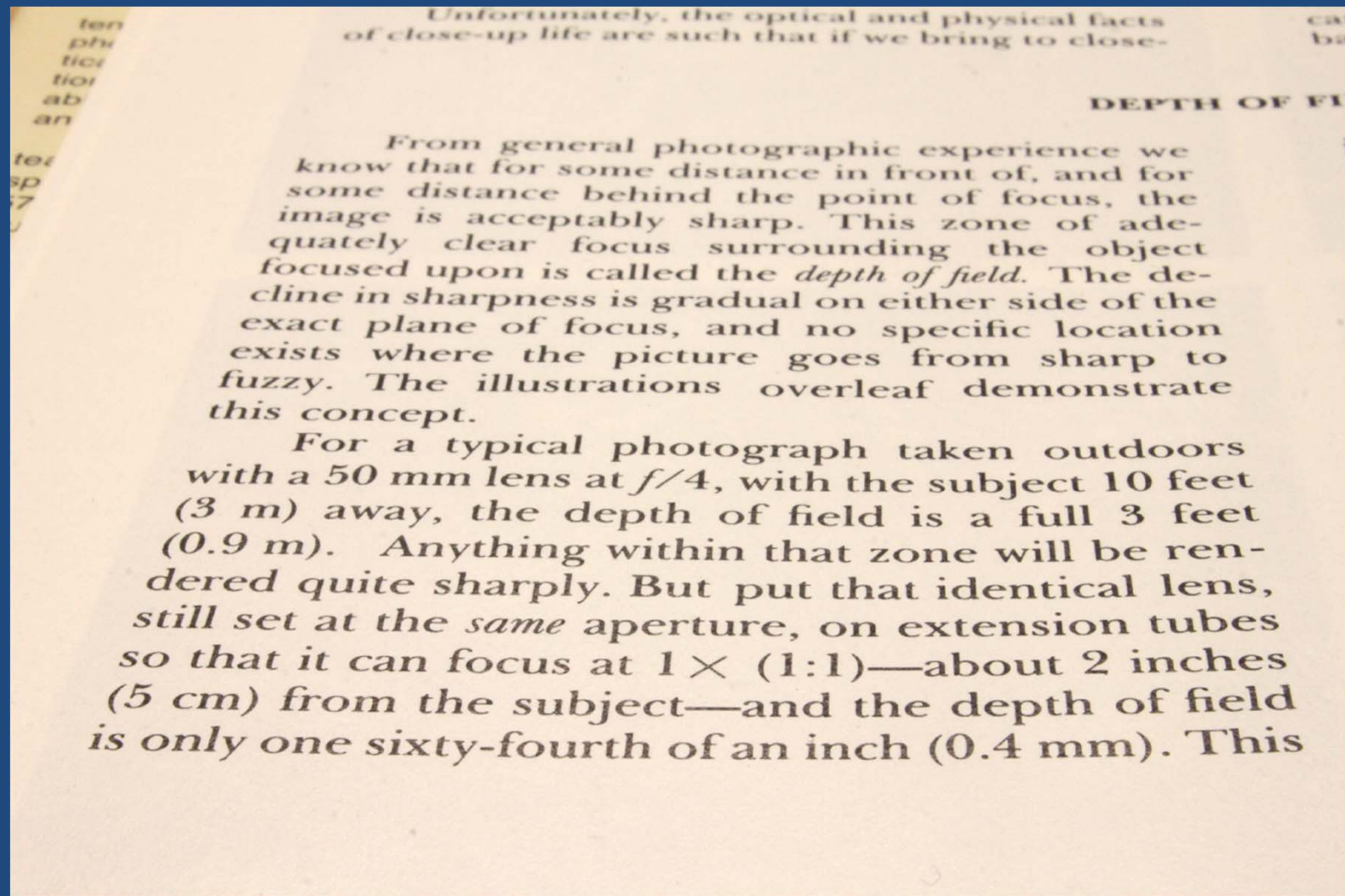
As Seen by the Camera (f/8)



Stacking 15 Frames (f/8)



A Single Frame (f/32)



Stacking 6 Frames (f/8)

From general photographic experience we know that for some distance in front of, and for some distance behind the point of focus, the image is acceptably sharp. This zone of adequately clear focus surrounding the object focused upon is called the *depth of field*. The decline in sharpness is gradual on either side of the exact plane of focus, and no specific location exists where the picture goes from sharp to fuzzy. The illustrations overleaf demonstrate this concept.

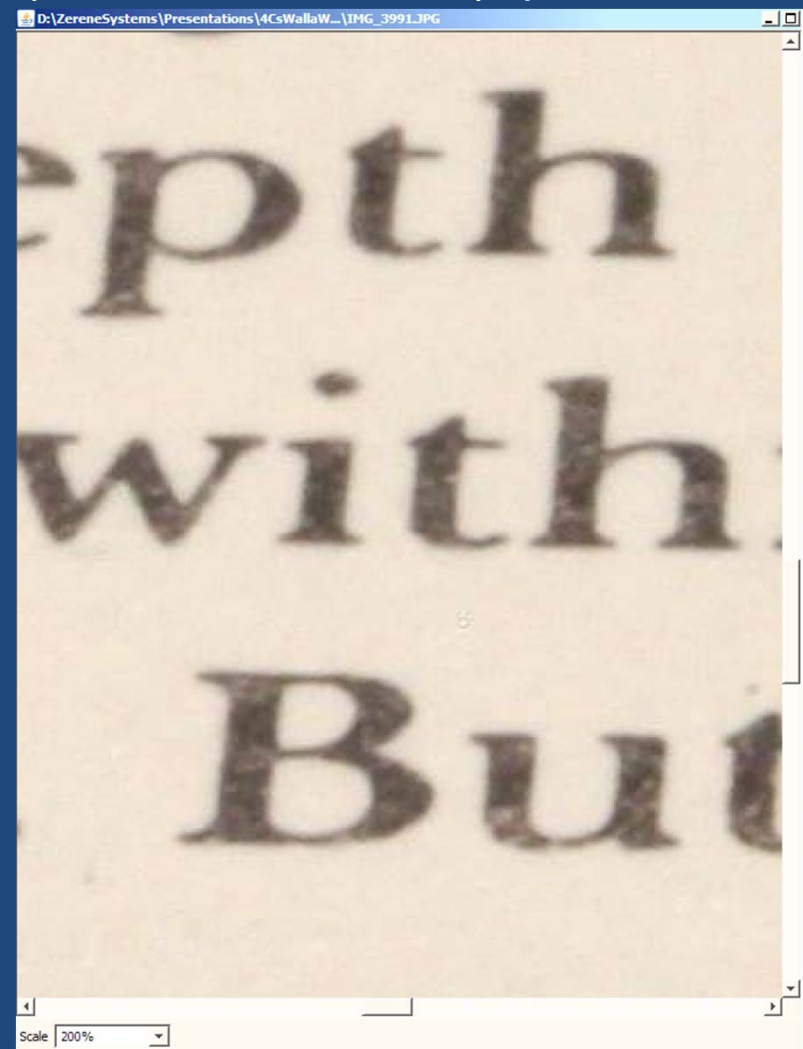
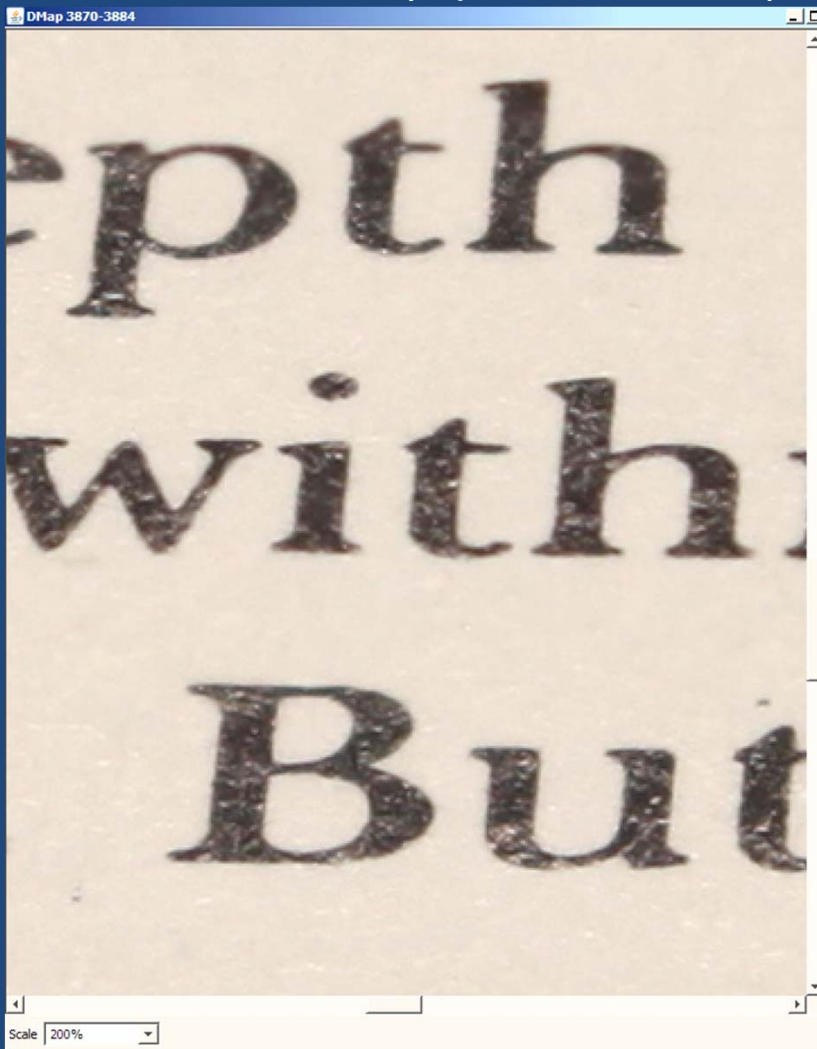
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Stacking Is Sharper Than Stopping Down

Stacked, f/8

(at 200%)

One Frame, f/32



Quick Recap So Far

Why: Get more depth of field, sharper subjects, smoother backgrounds

How:

Step 1) Shoot multiple images, changing focus.

Step 2) Run this “stack” of images through a computer to pick out the sharp bits.

You May Have a Few Questions...

The most common:

- How many frames do I need?
- What aperture should I use?
- How should I step focus?
- Should I use manual exposure, or automatic?
- Do I need any special equipment?
- What software should I use?
- How big of a computer does this take?

And the Answer Is...

“IT DEPENDS!”

How Many Frames Do I Need?

at least two



Painted hills with grass in foreground

sometimes hundreds



Fruit fly through 100X microscope

What Aperture Should I Use?

Best advice:

Stop down as far as possible,
while still getting the sharpness you want.

Three common choices:

1. Sharpest for the lens you're using
2. Farther open for more blurred background
3. Farther closed for fewer frames

How Should I Step Focus?

There are two common choices:

1. Turn the focus ring on the lens

- usually the best approach, if it's feasible at all

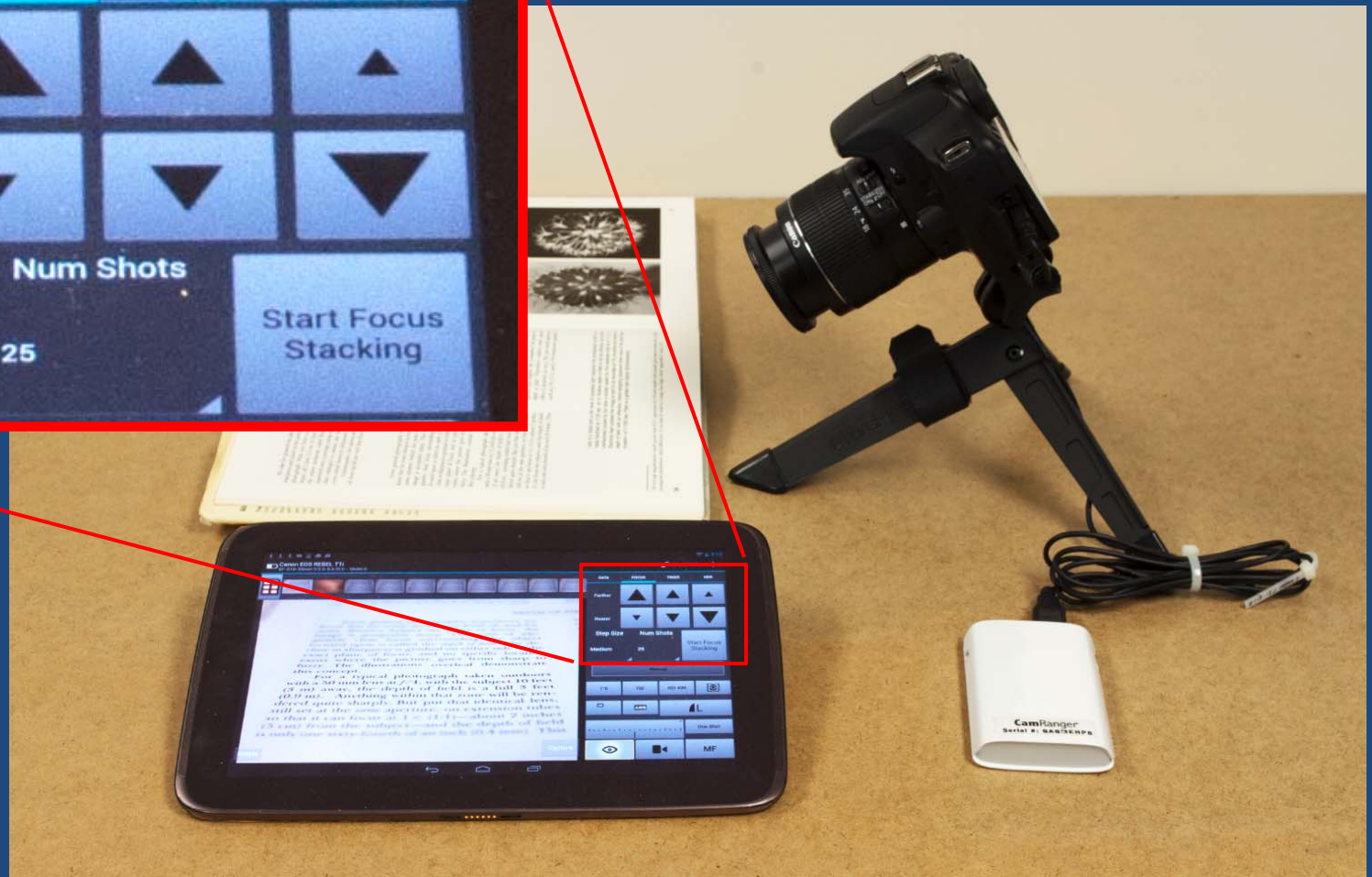
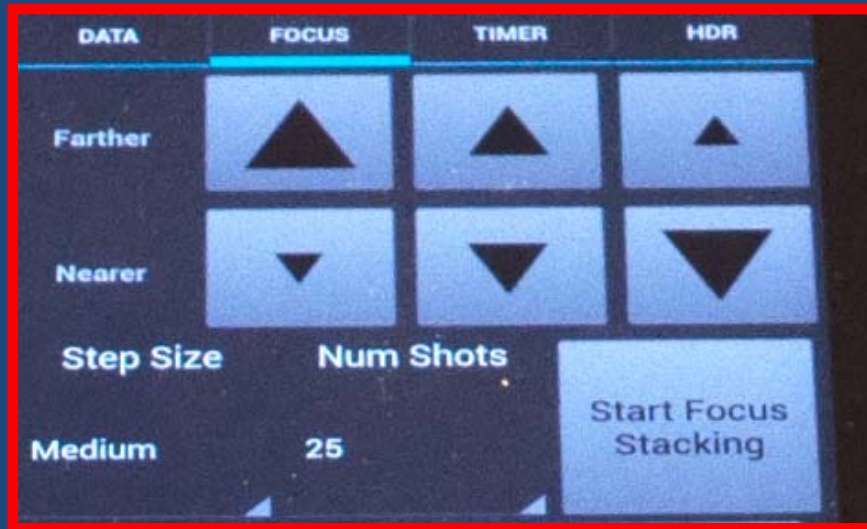
2. Move the camera and lens as a unit

- most effective with small subjects, e.g. $< 1''$

Both can be automated, if you like.

The Example Was Shot with CamRanger

Automated control of focus motor (“turn the ring”)



Stepping Focus: Lots of Options

Move the optics, move the camera



Move the subject



Every one of these methods is useful in some circumstances.

What's the Best Method To Step Focus?

(It depends...)

Type of Subject		Focusing Method							
Description	Typical # Frames	Lens Ring (manual)	Lens Ring (AF motor)	Focus Rail (gear)	Focus Rail (manual screw)	Focus Rail (motor screw)	Microscope Focus Block	Bellows Front	Bellows Rear
Landscape	5	Excellent	Excellent	Impossible	Impossible	Impossible	Impossible	Good	Ideal
Bouquet of flowers	10	Good	Excellent	Awful	Awful	Awful	Impossible	Good	Ideal
Single rose	20	Challenging	Excellent	Mediocre	Mediocre	Mediocre	Impossible	Mediocre	Ideal
Raisin	40	Challenging	Excellent	Good	Good	Good	Good	Awful	Excellent
Fruit Fly	200	varies!	varies!	Impossible	Tedious	Excellent	Excellent	Mediocre	Good
Eye of Fruit fly	many	varies!	varies!	Impossible	Difficult	Excellent	Excellent	Impossible	Mediocre

This is from the Zerene Stacker web page,

“Is it better to use a focus rail or the ring on my lens?”

So What Can Go Wrong?

- Changes of magnification are OK –
software can perfectly correct for those.
- Changes of perspective are a problem –
there's no way to correct for those.

Move the lens as little as possible.

Be sure nothing changes except focus.

Do Not Do This!

Focused on background leaf



and focused on foreground petal



Do Not Do This!

and focused on foreground petal



and focused on foreground petal

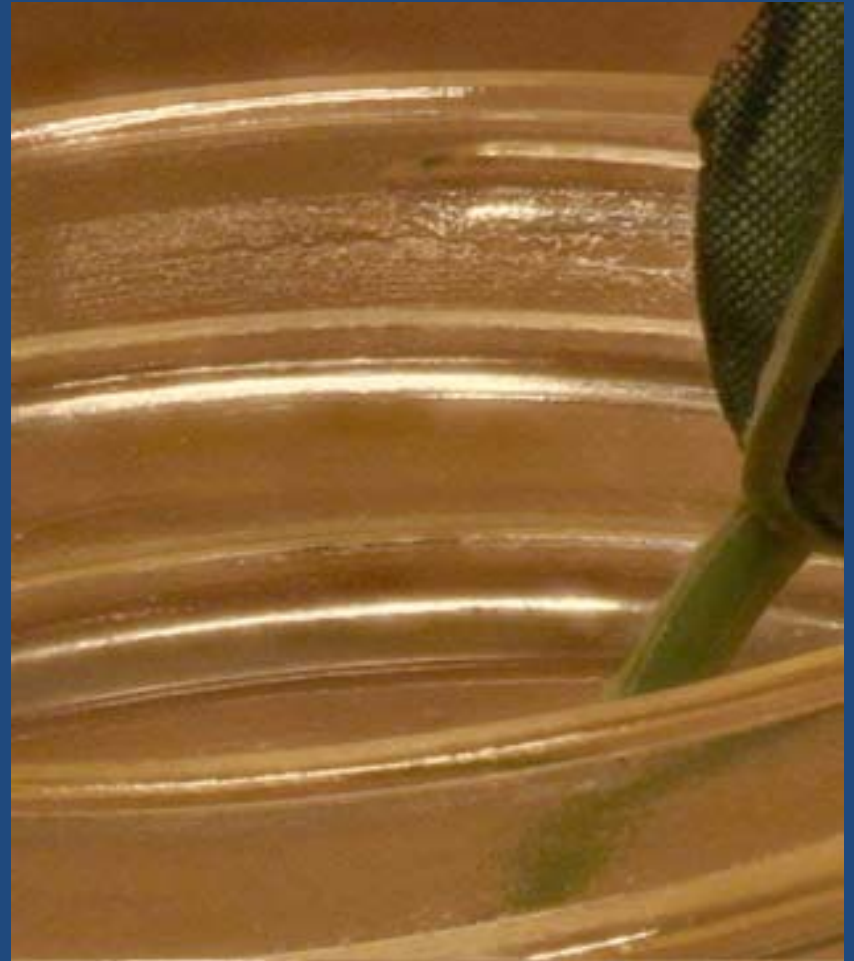


Compare The Results

Focused “by rail”



Focused “by ring”



Automation For Stepping Focus

(This list is not exhaustive...)

- AF motor control to “turn the focus ring”
 - CamRanger
(Canon & Nikon, wireless to smartphone, tablet, laptop, even desktop)
 - Helicon Remote (Canon & Nikon, multiple platforms, mostly wired, no iOS)
 - Magic Lantern (Canon only, runs inside camera)
 - DslrController (Canon wired to Android tablet or smartphone)
 - qDslrDashboard (Canon & Nikon, multiple platforms, mostly wired)
 - ControlMyNikon (Nikon only, Windows only, but very good)
 - Breeze Systems DSLR Remote Pro & NKRemote
(Canon & Nikon on Windows, Canon only on Mac)
- Automated focus rail
 - StackShot

StackShot Rail

Automated stepping to 2 μm (0.002 mm = 0.00008)



Which Software?

Reasonable options:

- **Zerene Stacker**
 - popular and powerful
 - more Flickr postings & Nikon Small World winners than all others combined
- Photoshop CS4 and later, full version only
 - most commonly installed, but also the lowest quality for this job
- Helicon Focus — longest history, good functionality
- Affinity Photo — newest, like Photoshop but one-time purchase



Other Common Questions

What kind of computer?

- Most modern ones work fine.
- Zerene Stacker works on Windows, Mac, Linux, prefers 1 GB every 10 megapixels, no limit on # of frames.

Do I need special equipment?

- No, but you might want some after a while.
- Focus stacking allows closer macro than ever before.

Let's Run Another Example...

- Close up with some flowers in a garden
- Canon T1i DSLR with 18-55 mm kit lens
- CamRanger for wireless focus control
- Process in Zerene Stacker
- Brief comparison with Photoshop

Shooting With The CamRanger

Subject , Camera,
and CamRanger
(on tripod in garden)

Camera Controls and Live View
(on Android tablet in kitchen)



CamRanger Connected To Camera



Camera
(with battery installed)

USB cable

CamRanger
(with built-in battery)

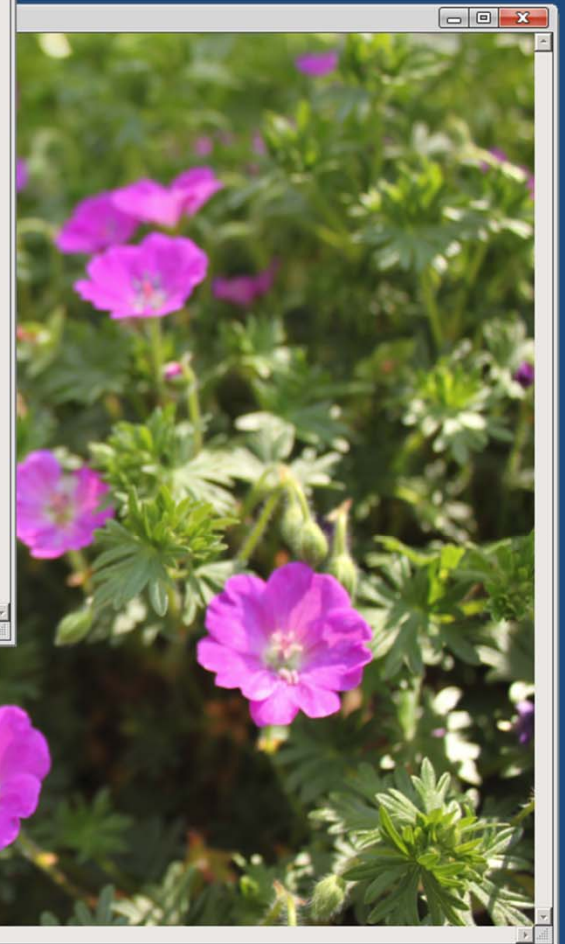
CamRanger Screen On Tablet



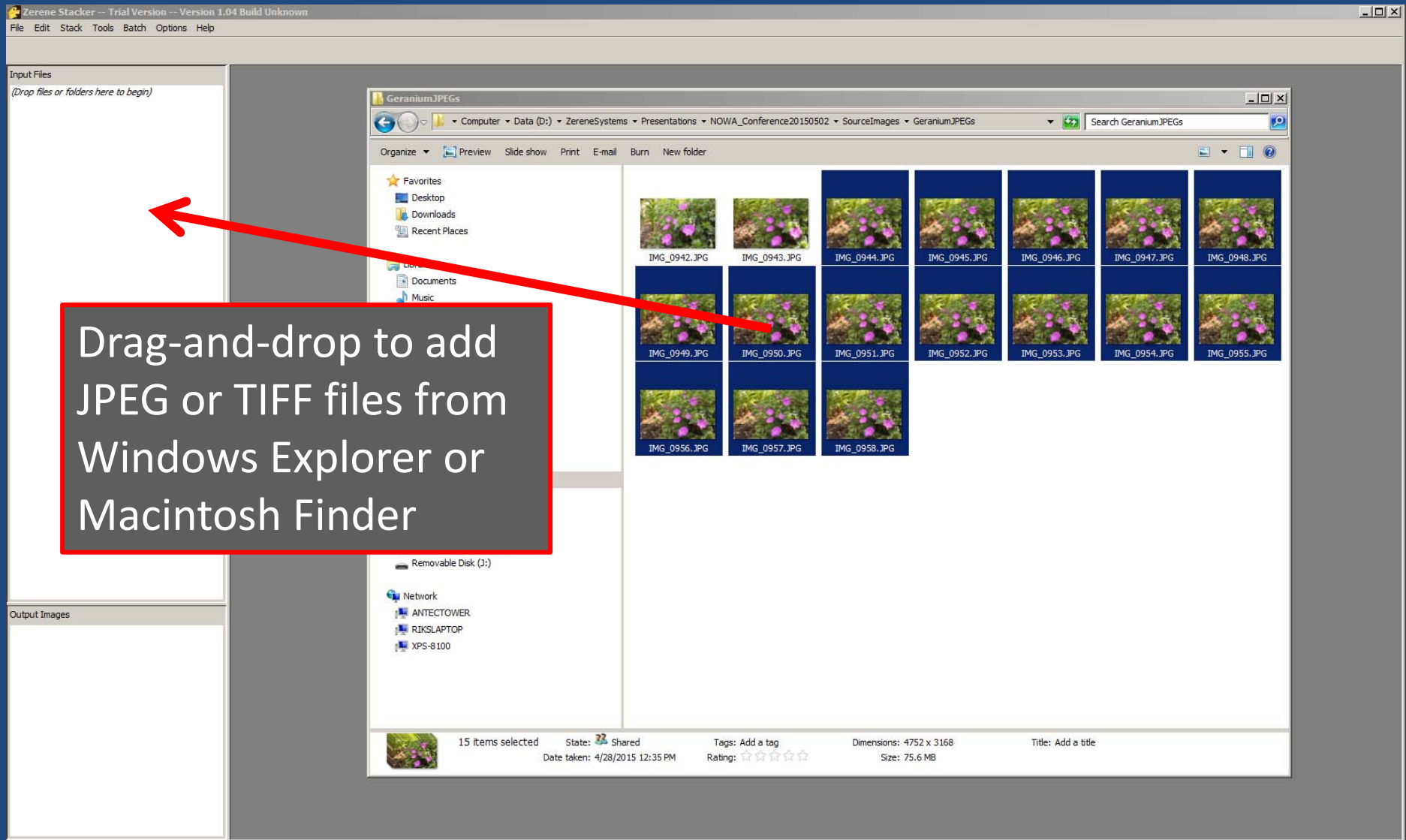
We Now Have A Stack



15 frames
at f/4

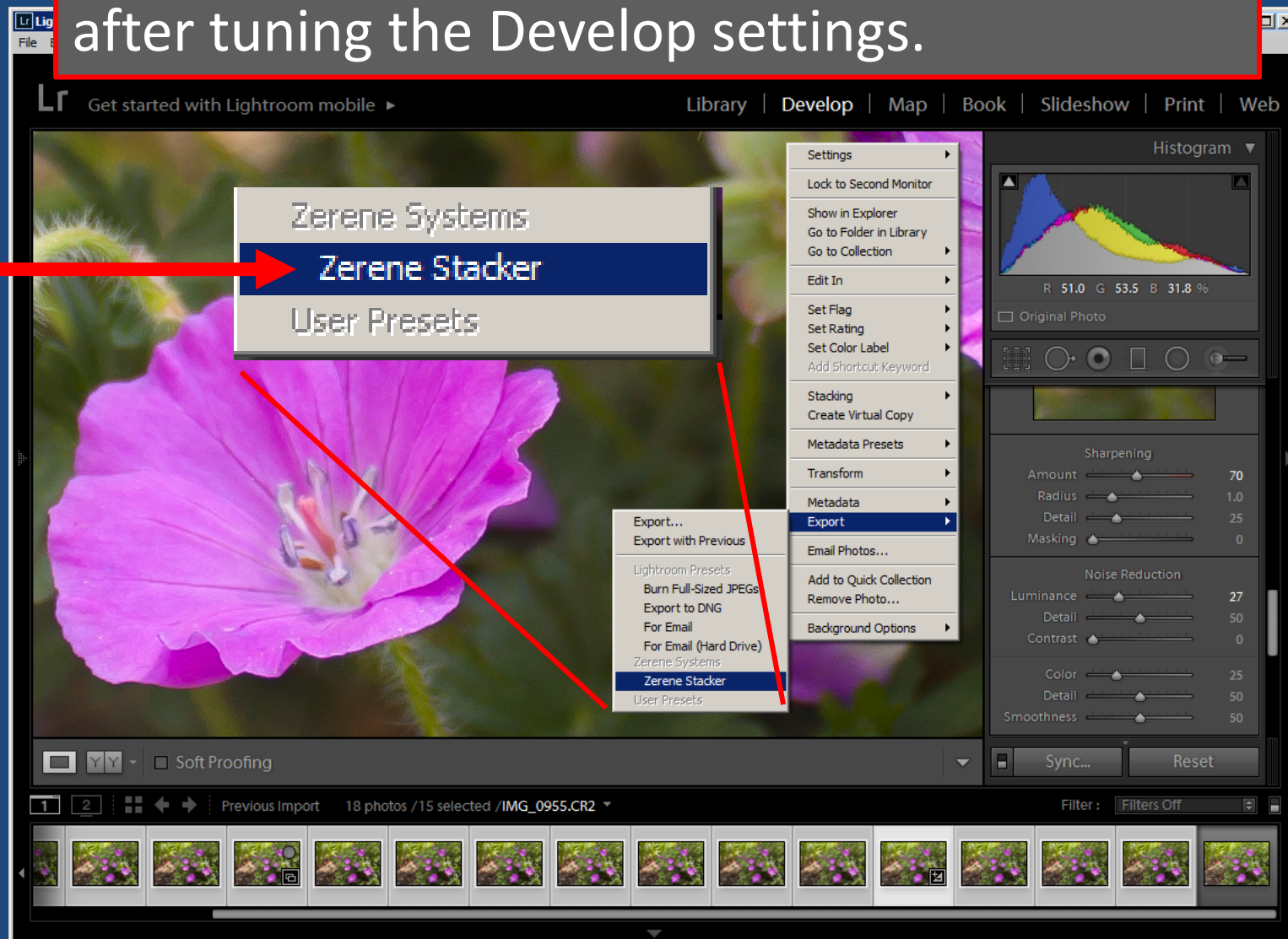


Load Images into Zerene Stacker

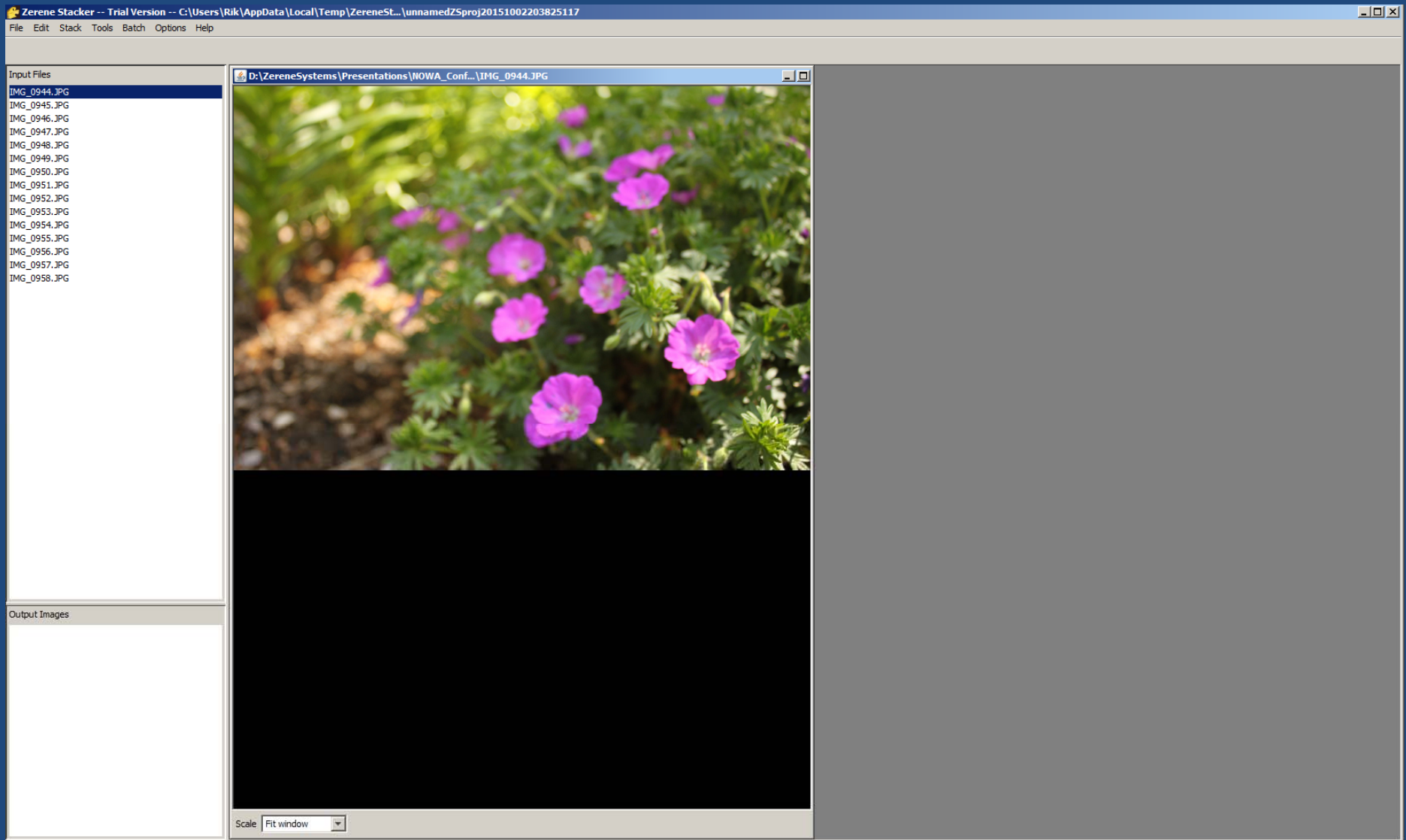


Load Images into Zerene Stacker

Select and Export any format from Lightroom, after tuning the Develop settings.

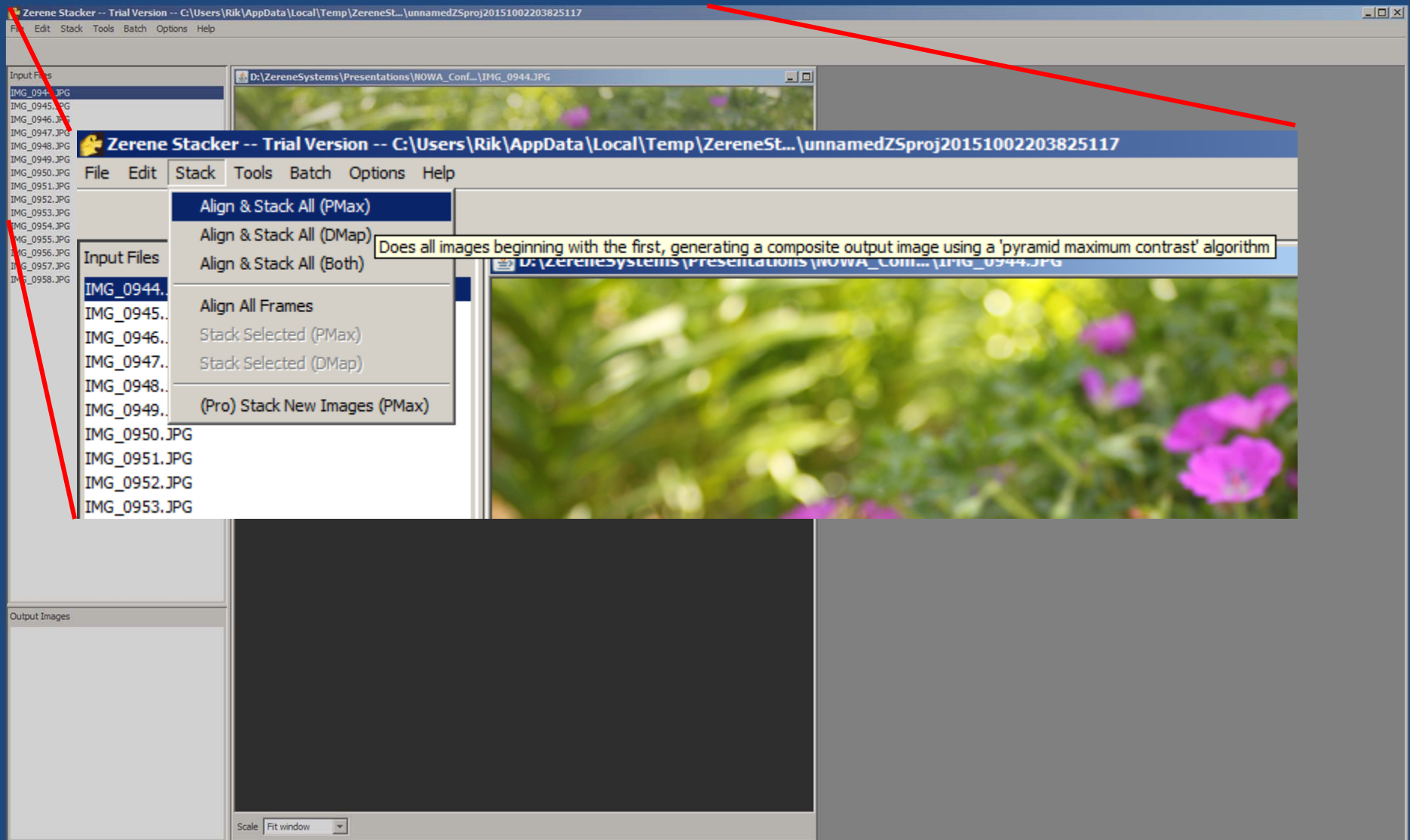


Processing in Zerene Stacker

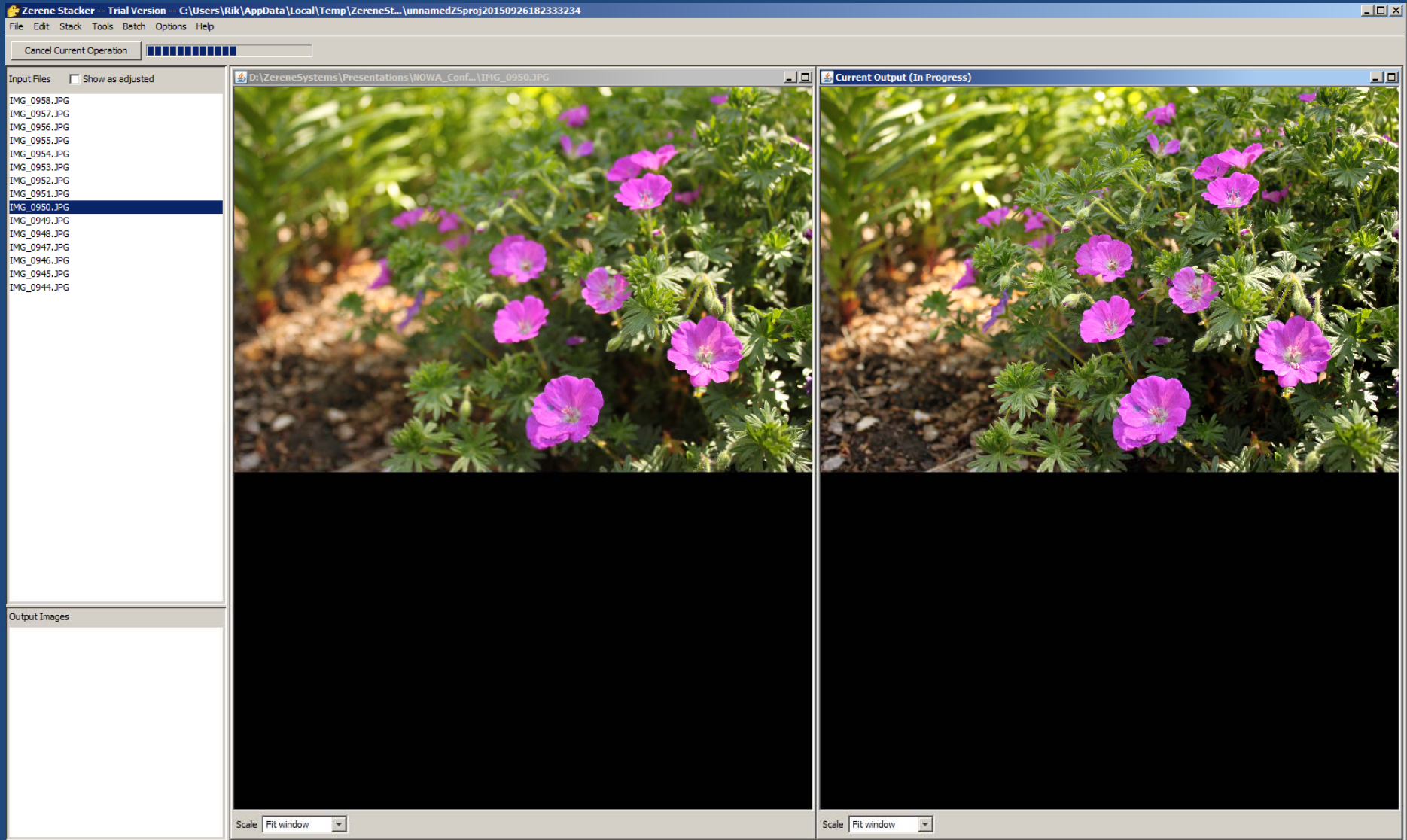


Processing in Zerene Stacker

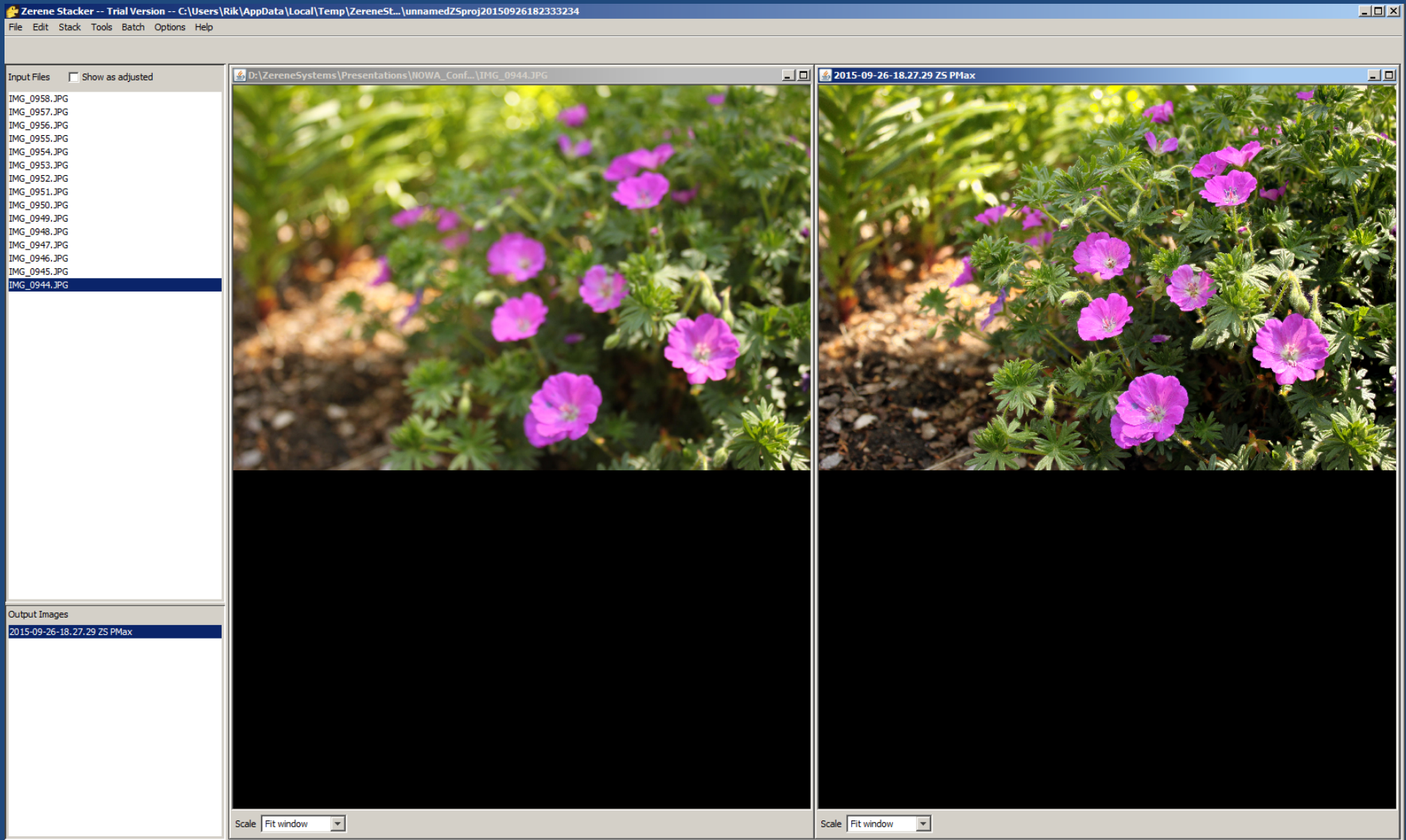
PMax method (“Pyramid Maximum”)



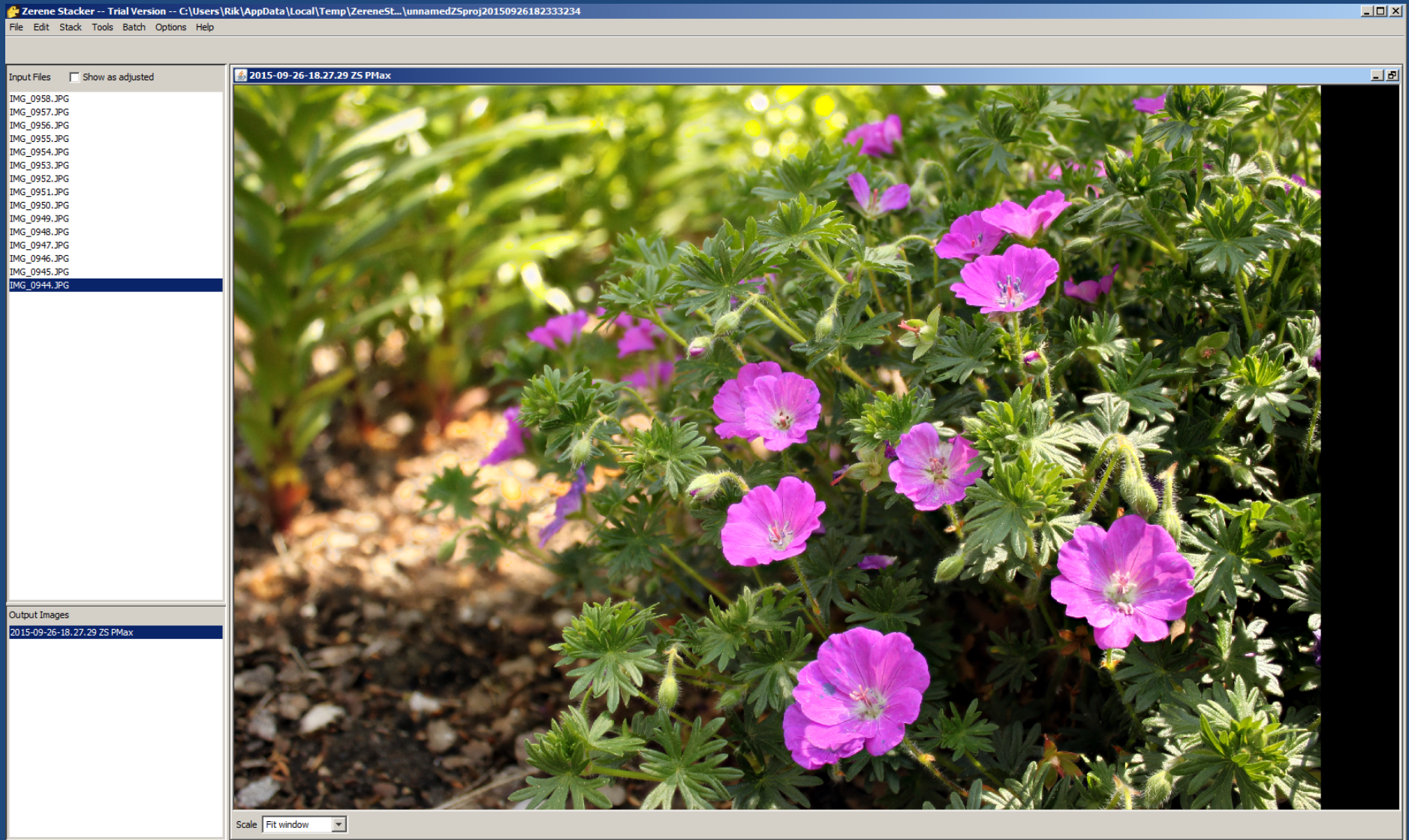
Processing in Zerene Stacker



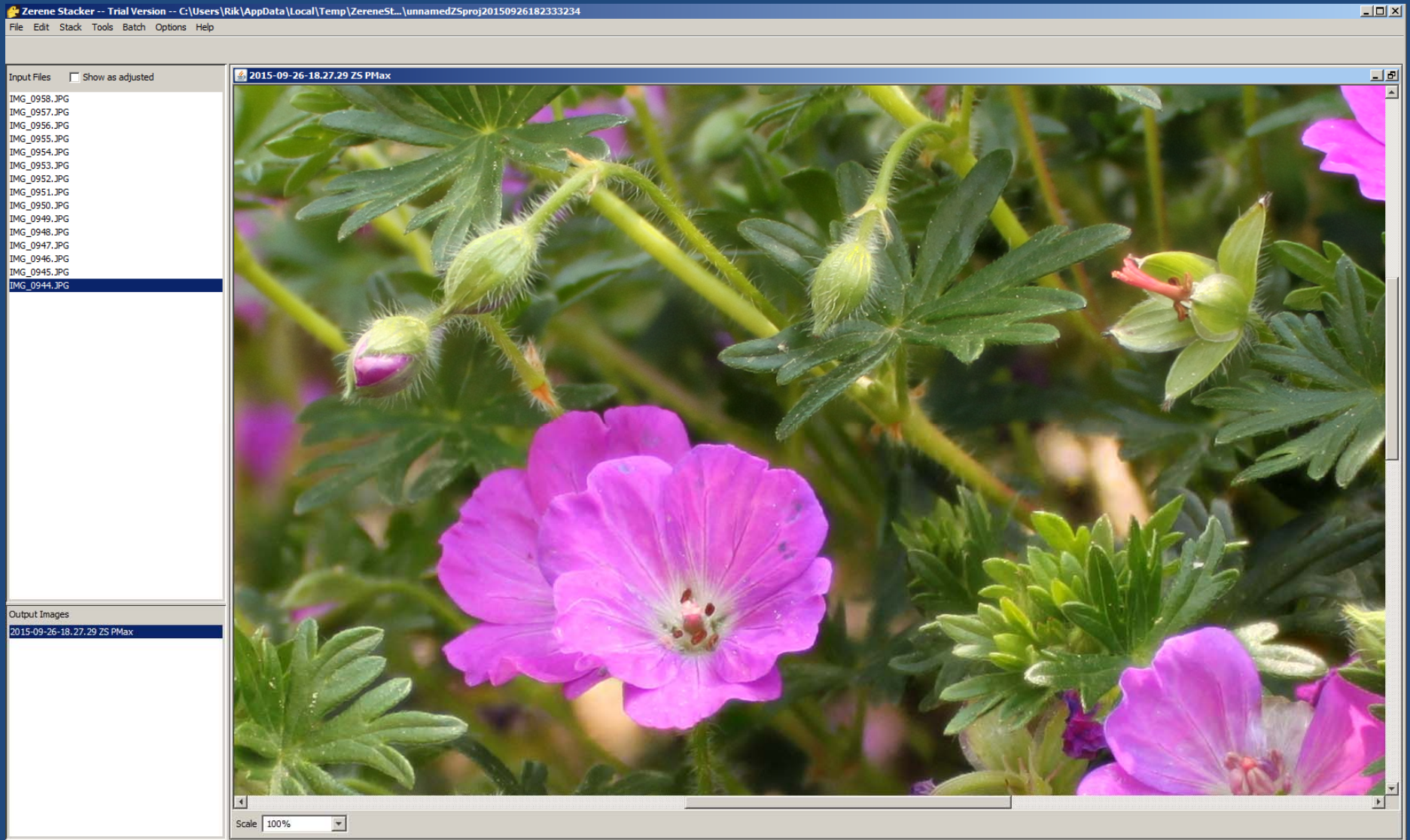
Processing in Zerene Stacker



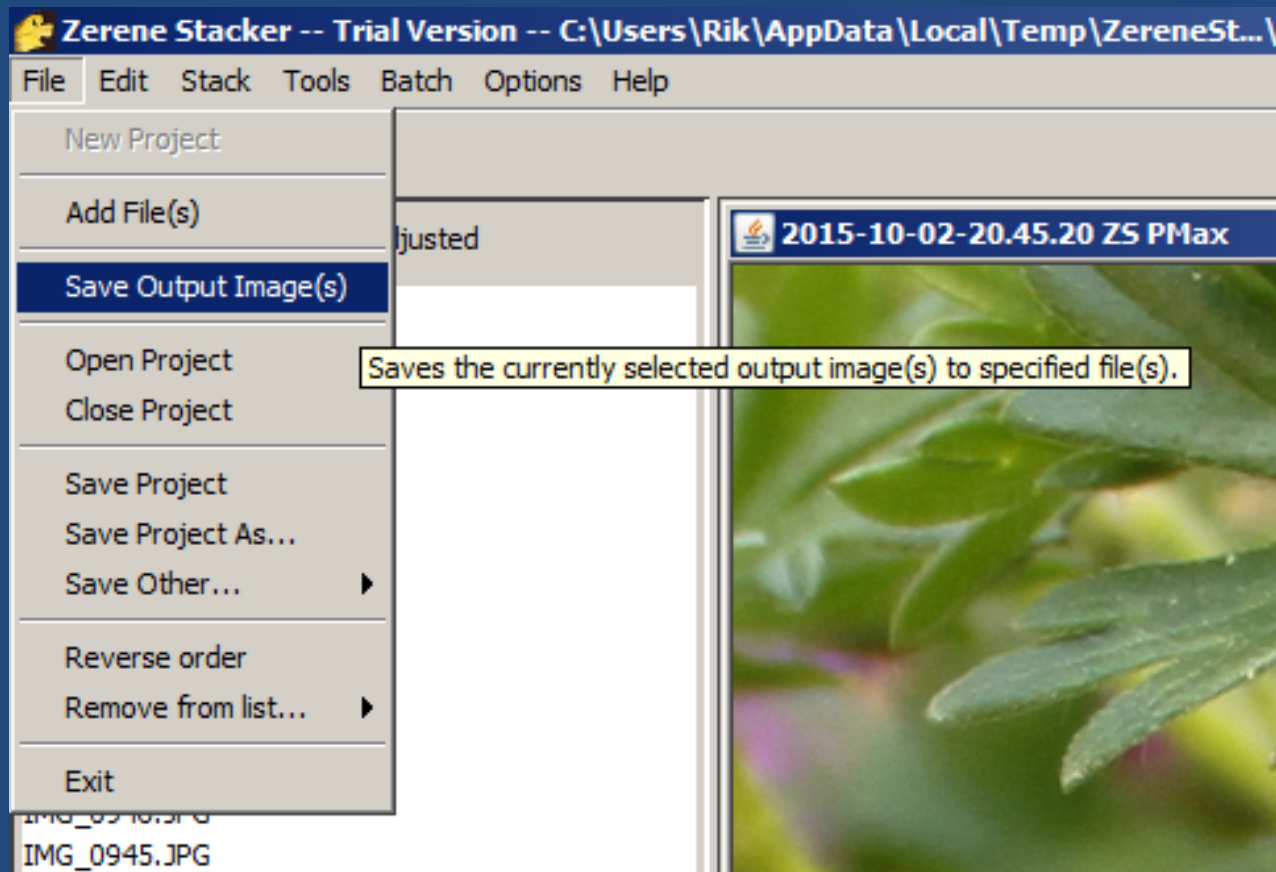
Processing in Zerene Stacker



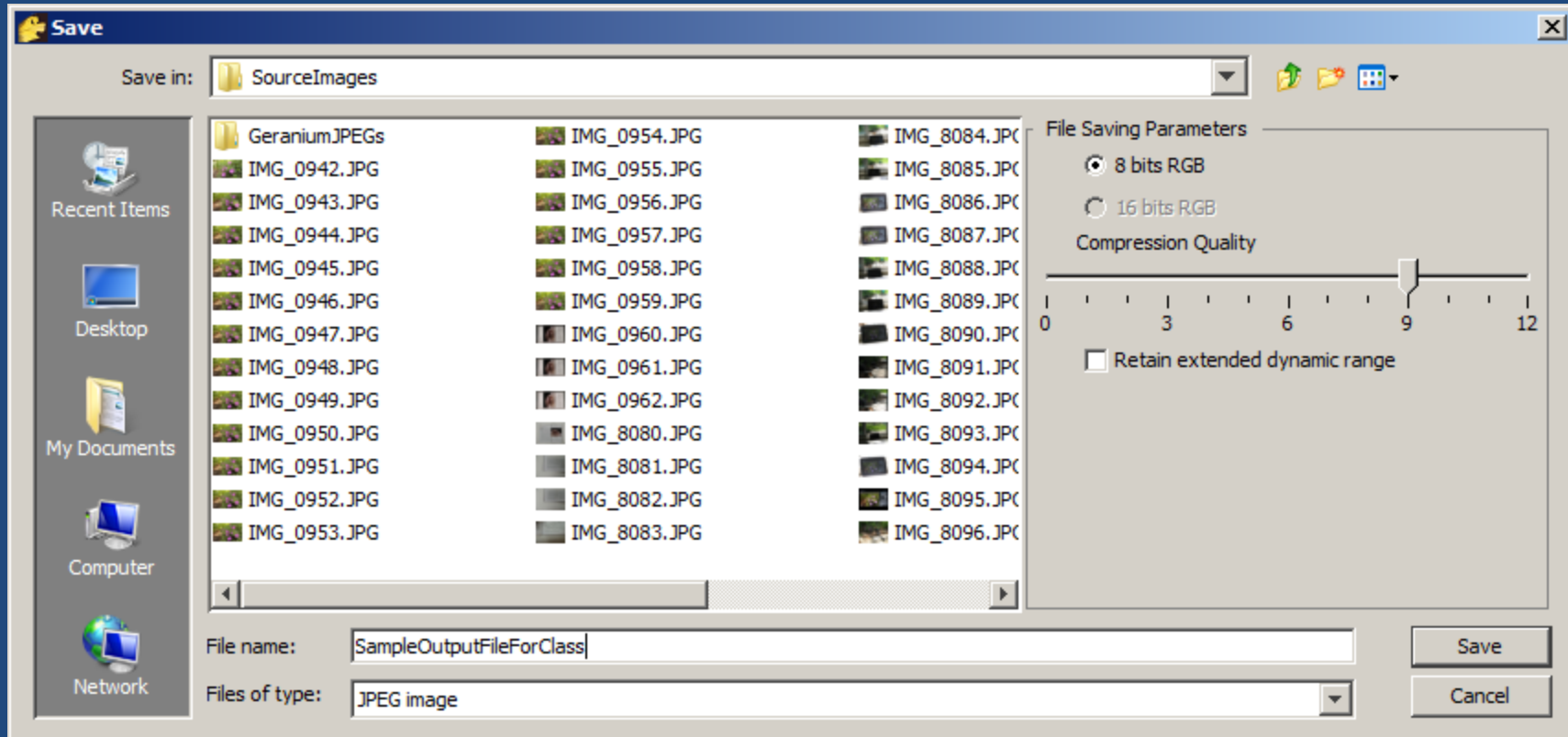
Processing in Zerene Stacker



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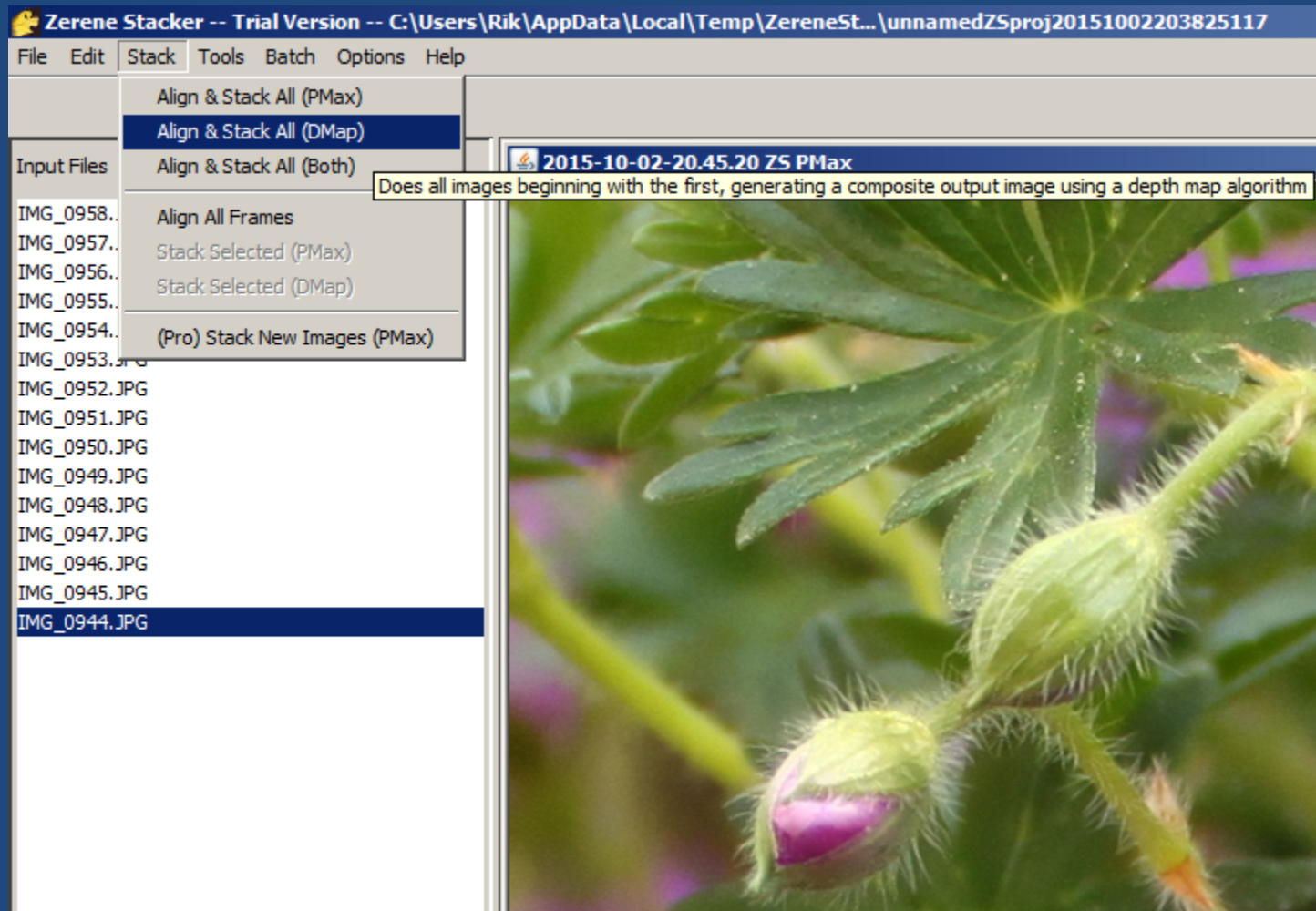


Processing in Zerene Stacker



Processing in Zerene Stacker

DMap method (“Depth Map”)



PMax versus DMap

A Quick Comparison

PMax

- + No learning curve
- + Better with tricky overlaps
- Accumulates noise
- Alters contrast and colors

Best for:

Bristly bugs, complex foliage

DMap

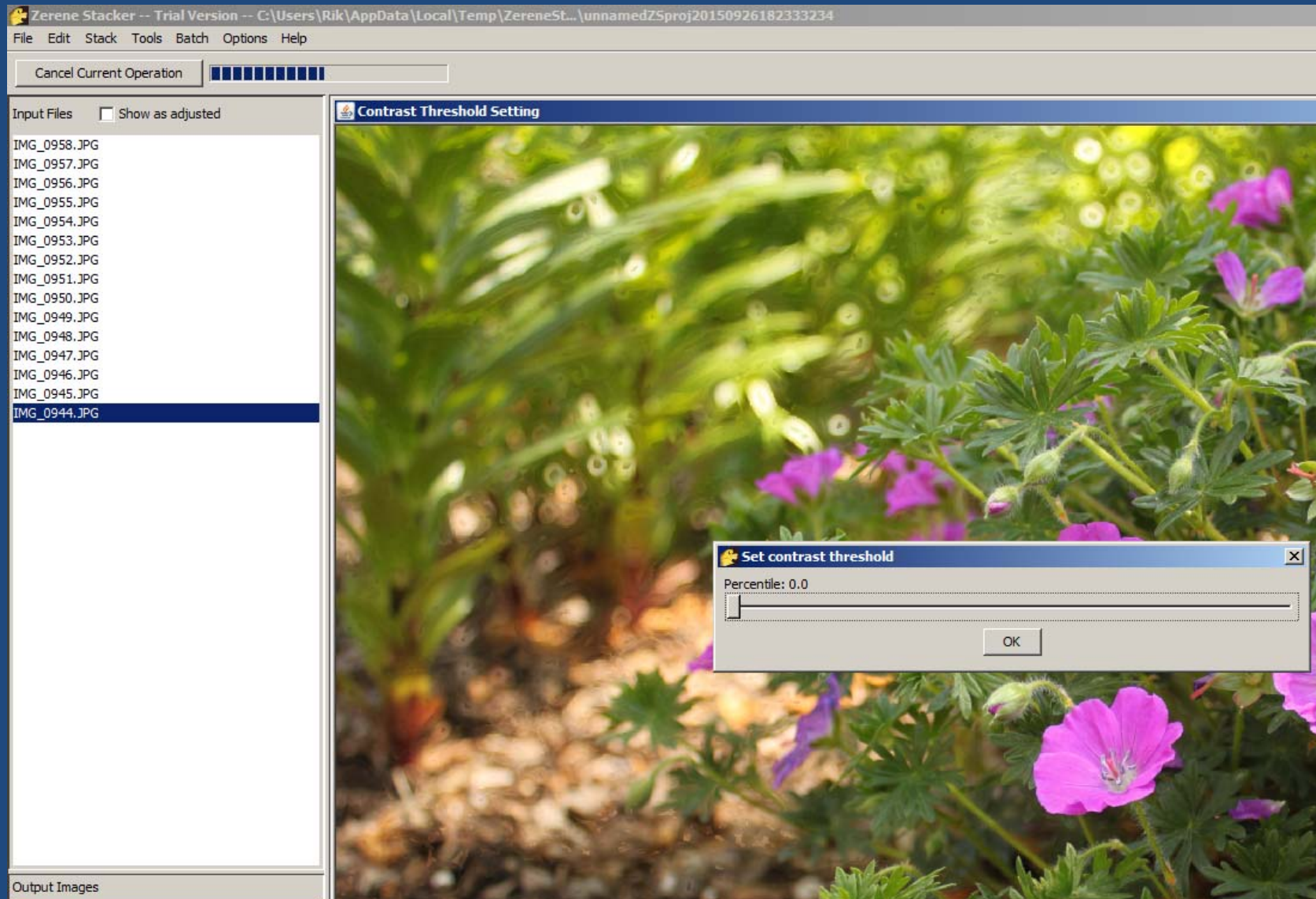
- Several controls to learn
- Not as good with overlaps
- + Does not accumulate noise
- + Does not alter color/contrast

Best for:

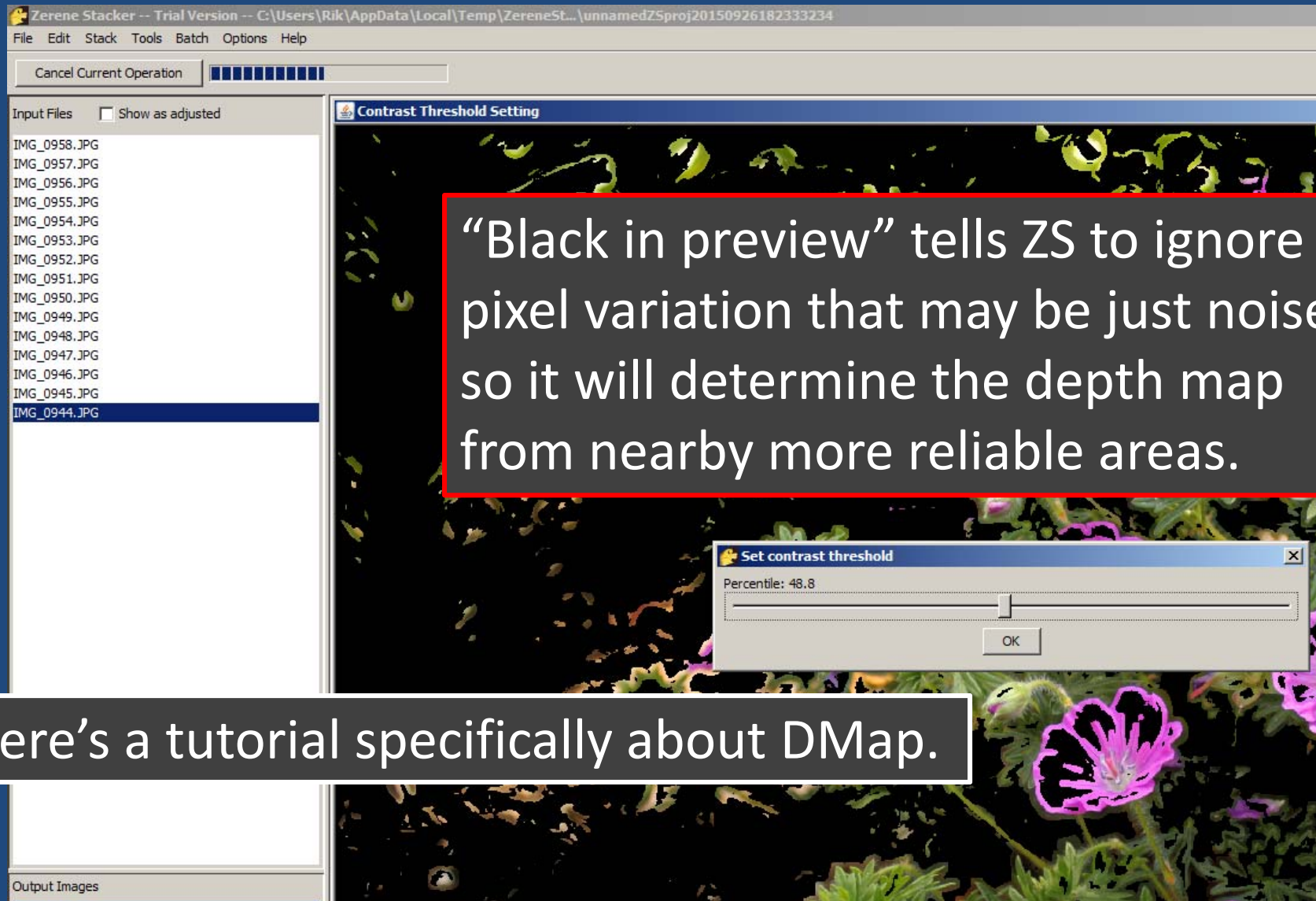
Rich tones and colors

Often it's best to combine these by retouching.

Processing in Zerene Stacker

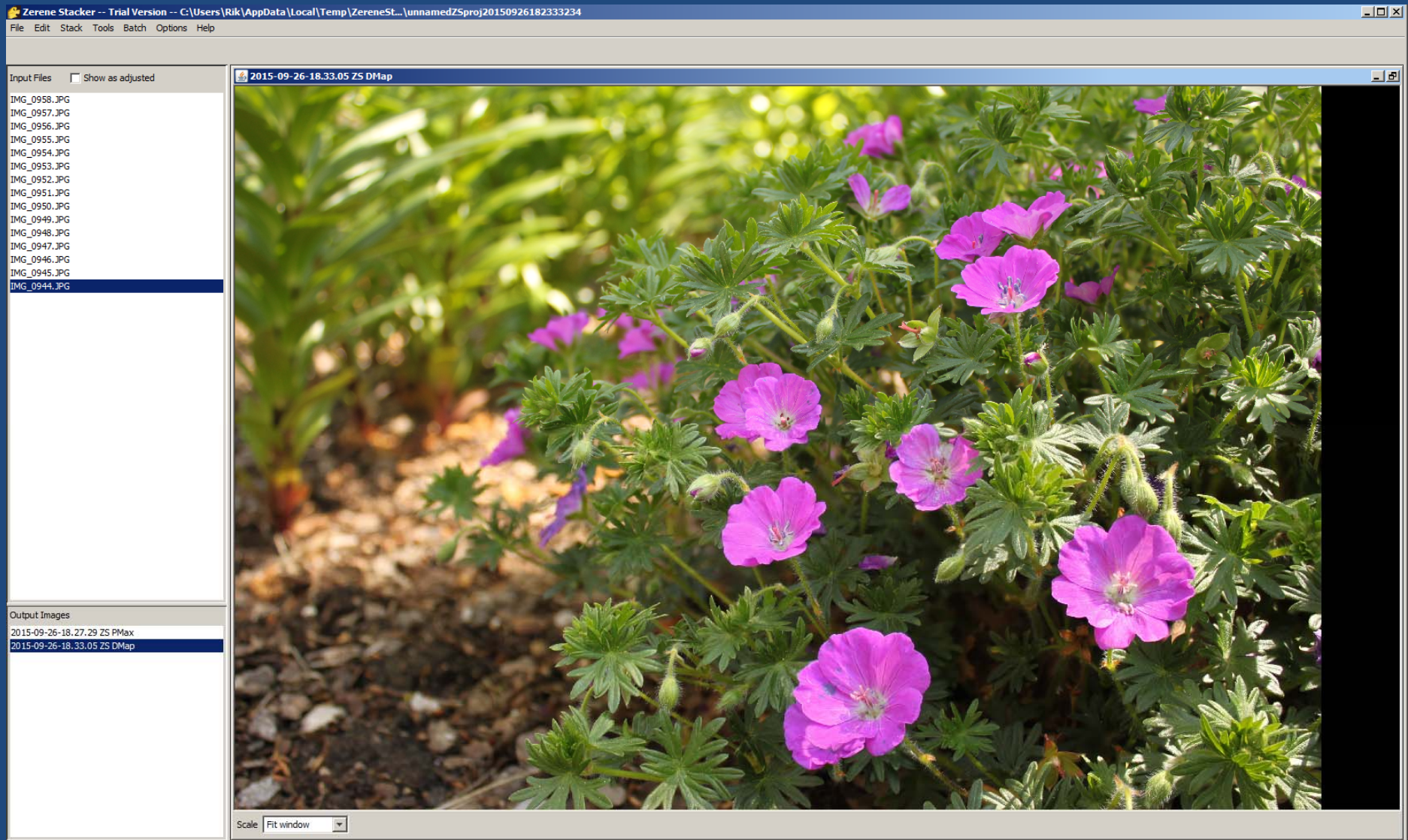


Processing in Zerene Stacker

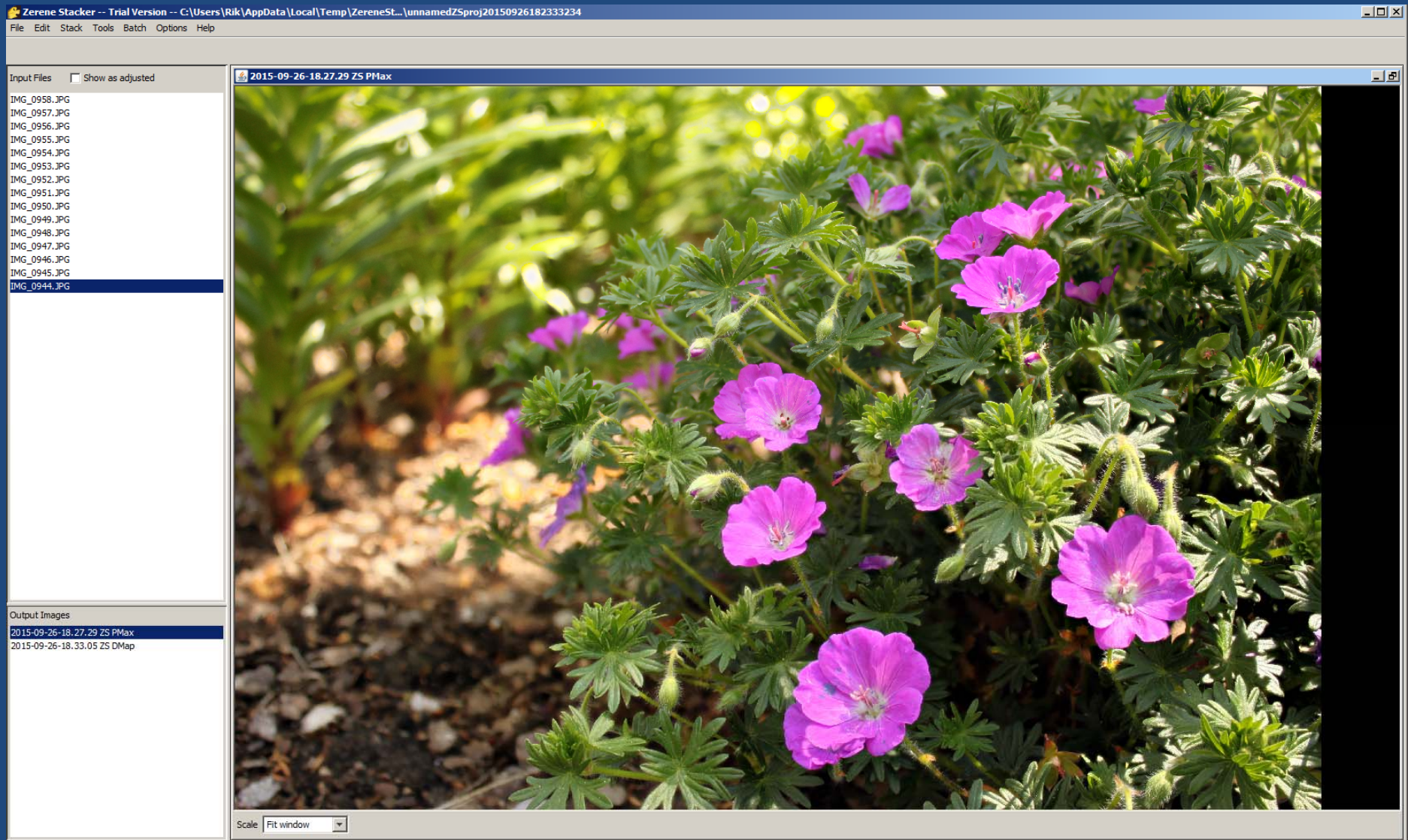


There's a tutorial specifically about DMap.

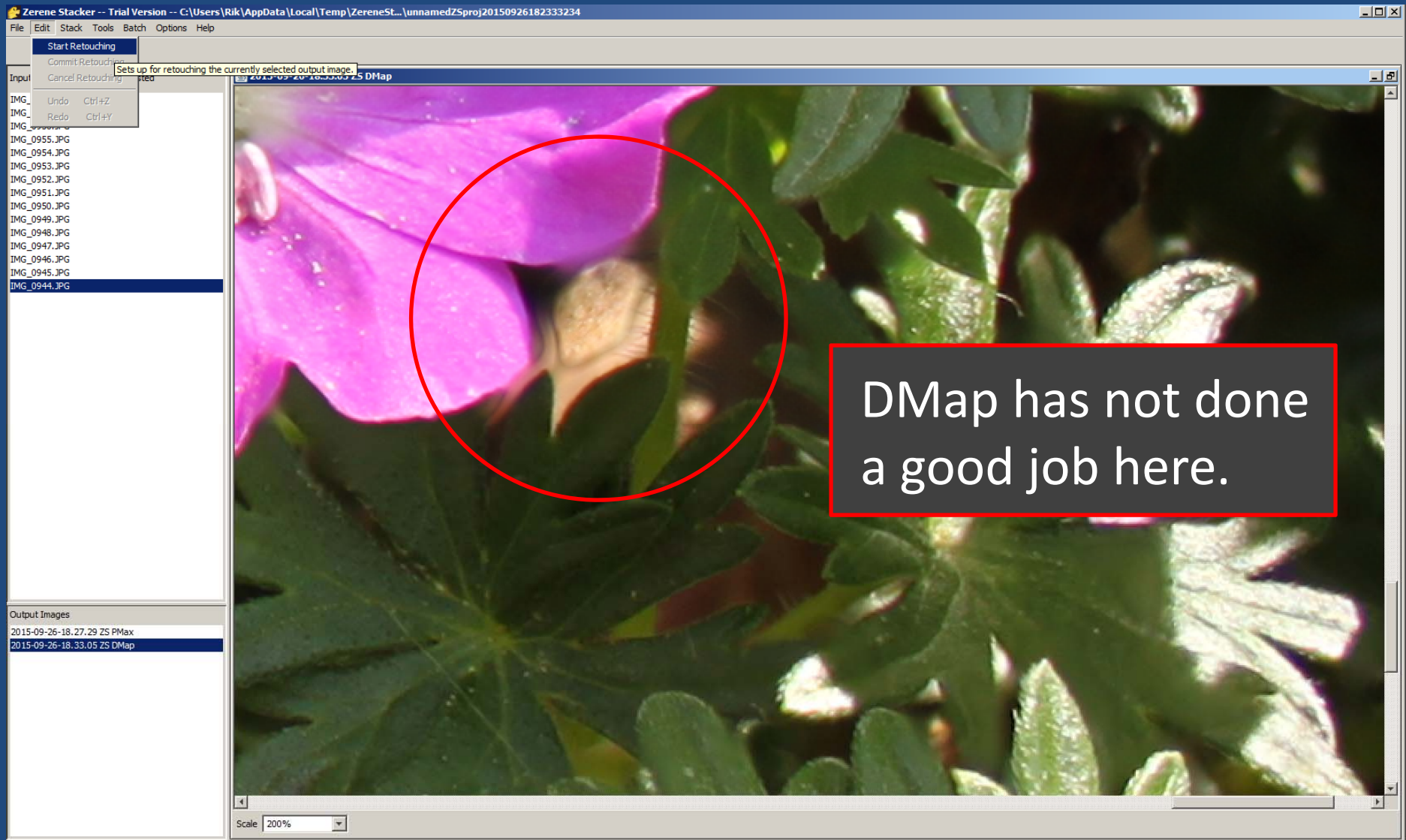
Processing in Zerene Stacker



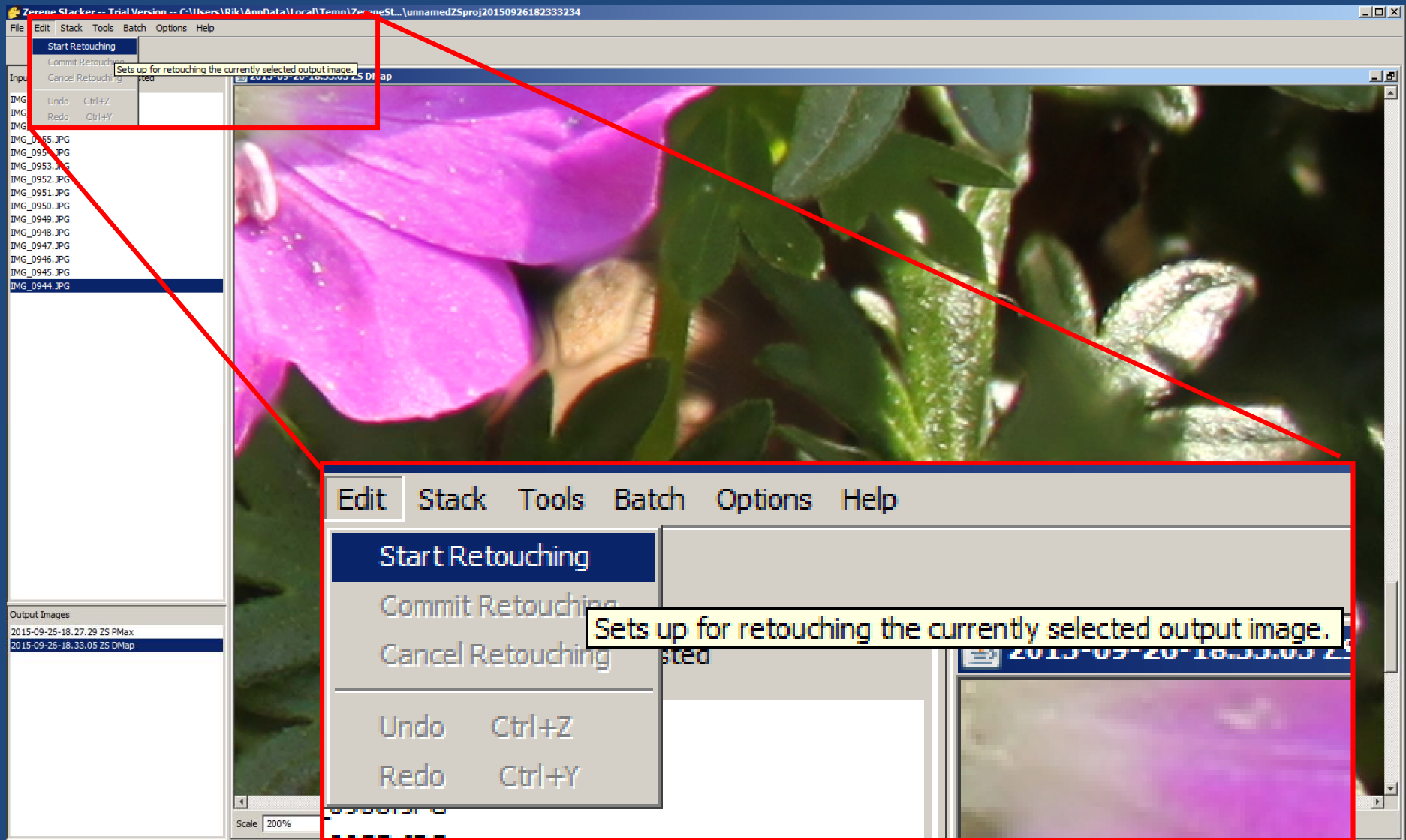
Processing in Zerene Stacker



Processing in Zerene Stacker

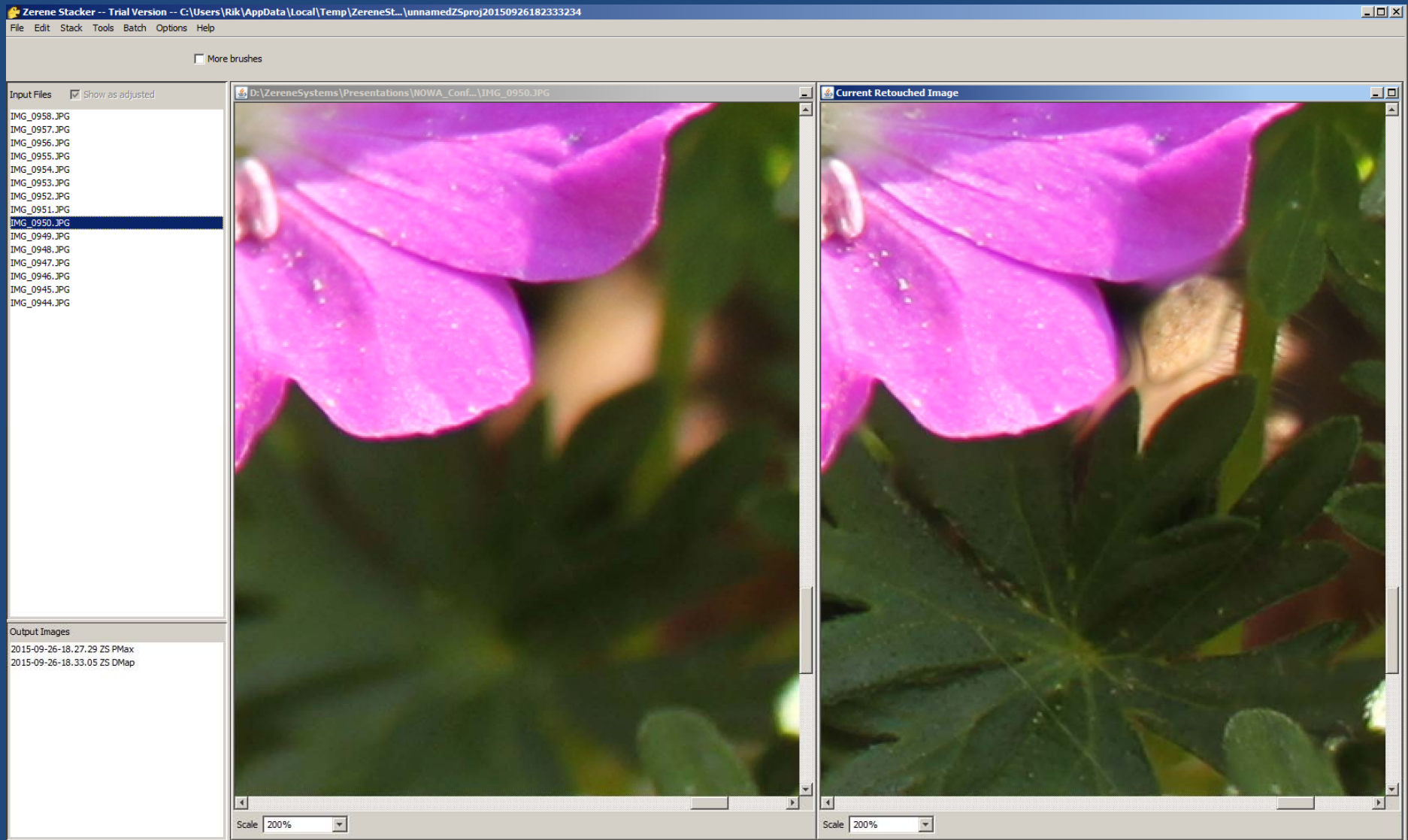


Processing in Zerene Stacker



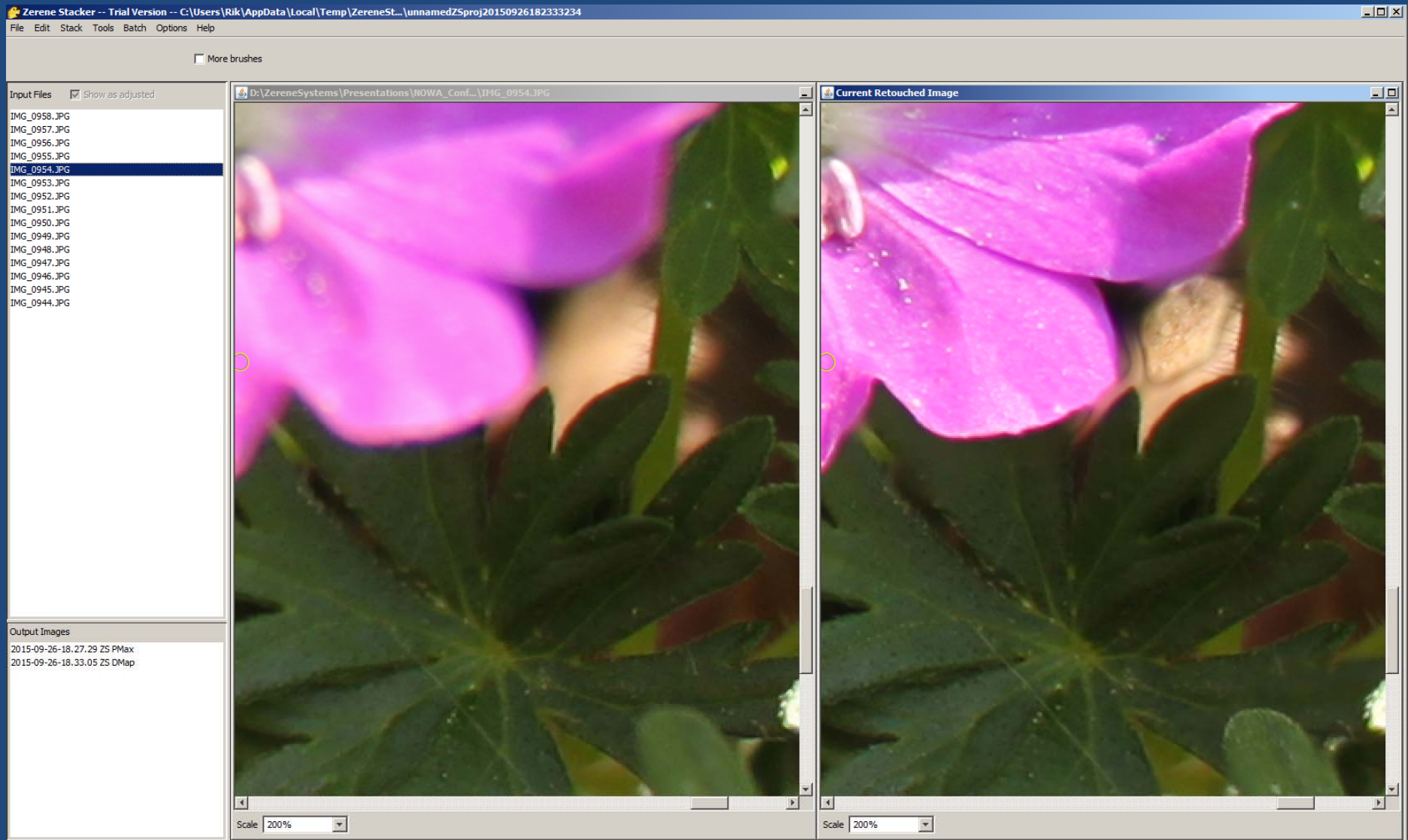
Processing in Zerene Stacker

Three input images contribute to this area



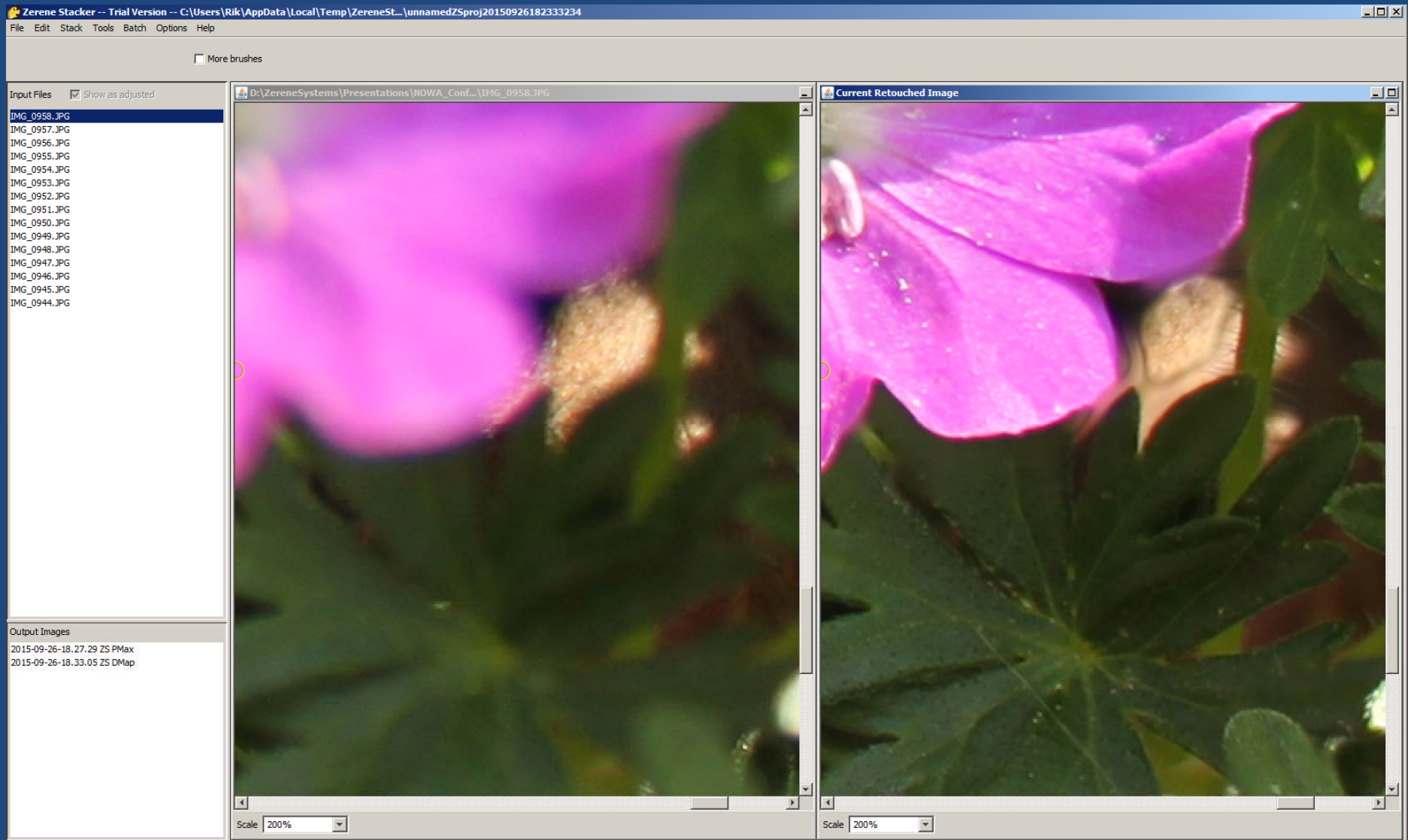
Processing in Zerene Stacker

Three input images contribute to this area



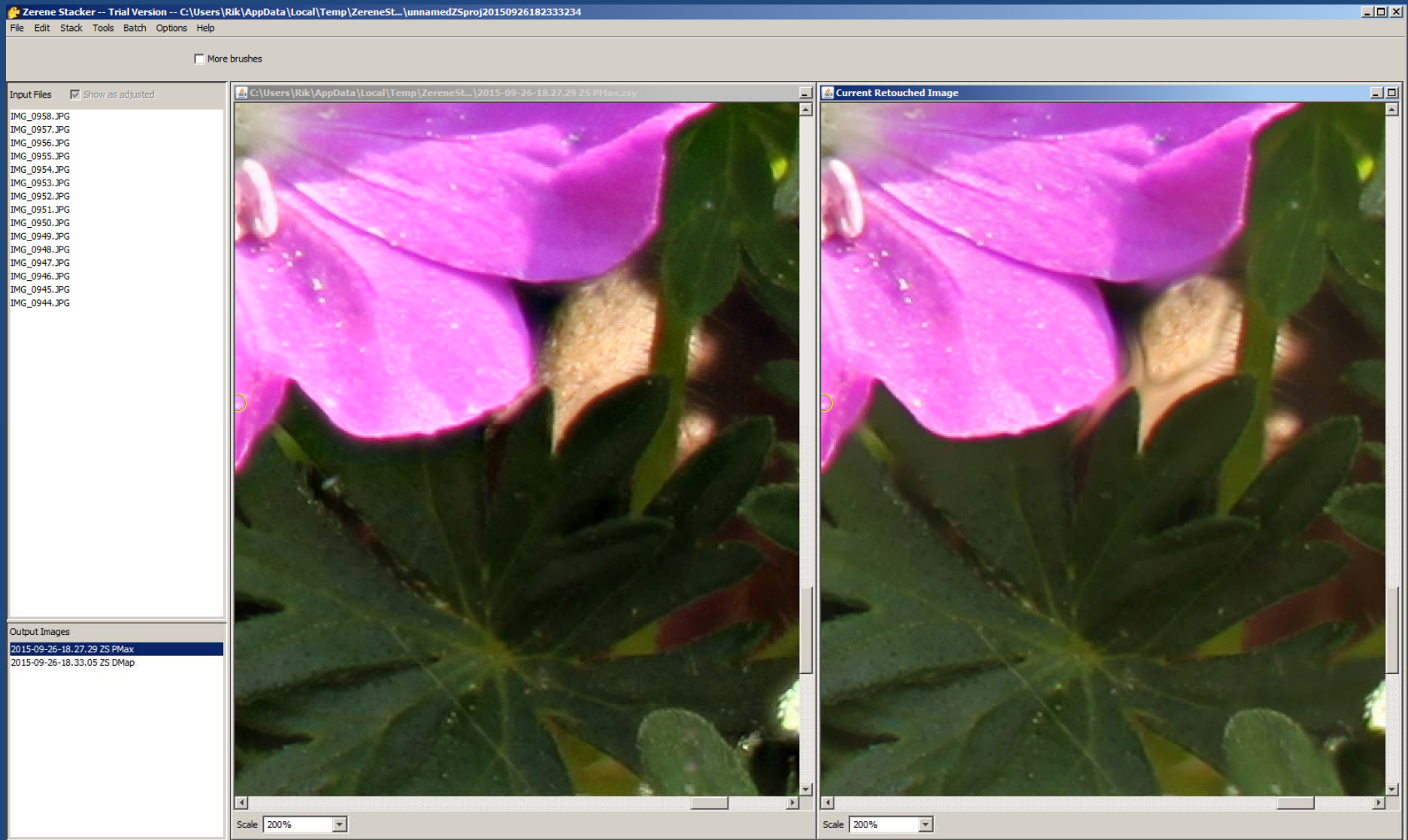
Processing in Zerene Stacker

Three input images contribute to this area

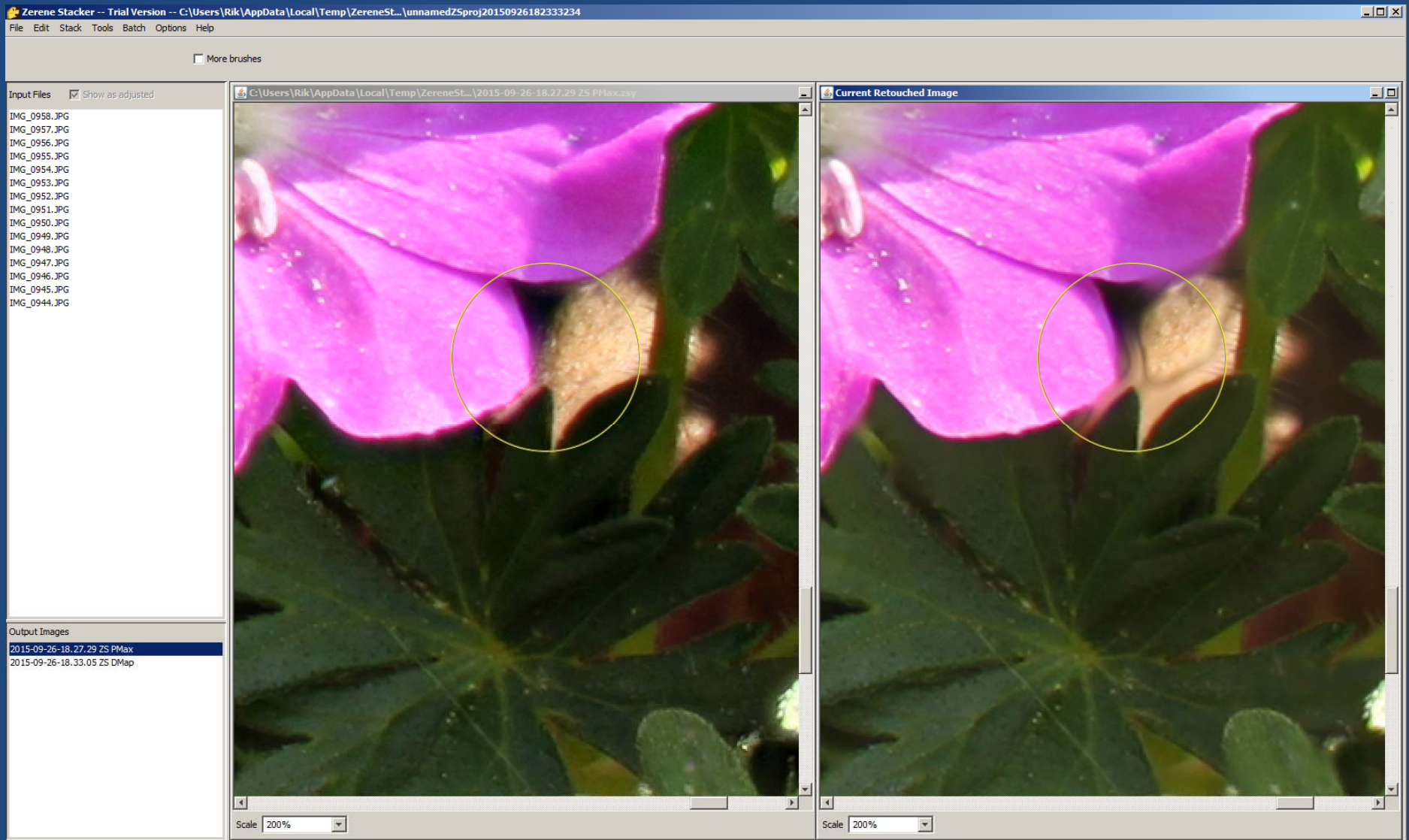


Processing in Zerene Stacker

PMax puts them together cleanly

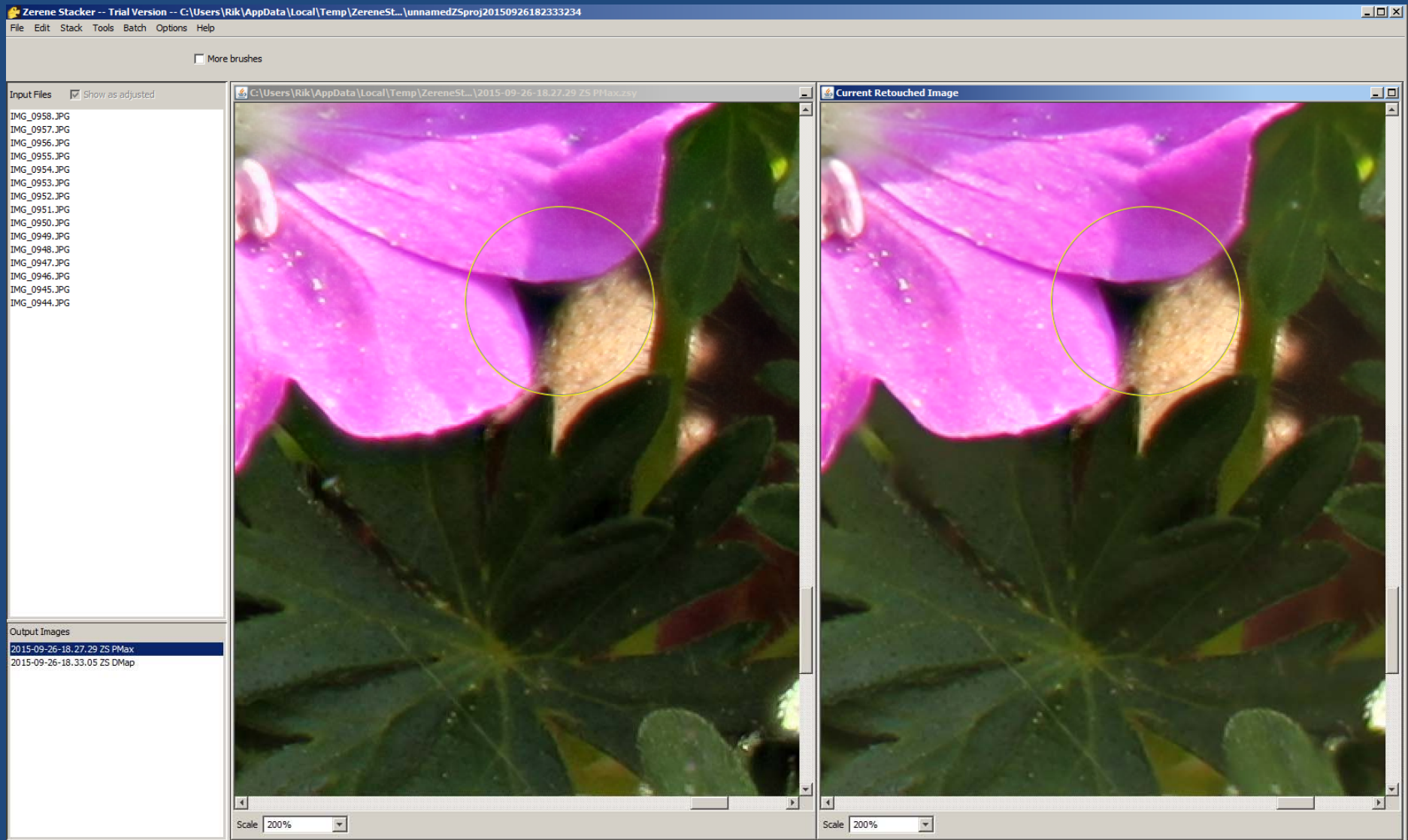


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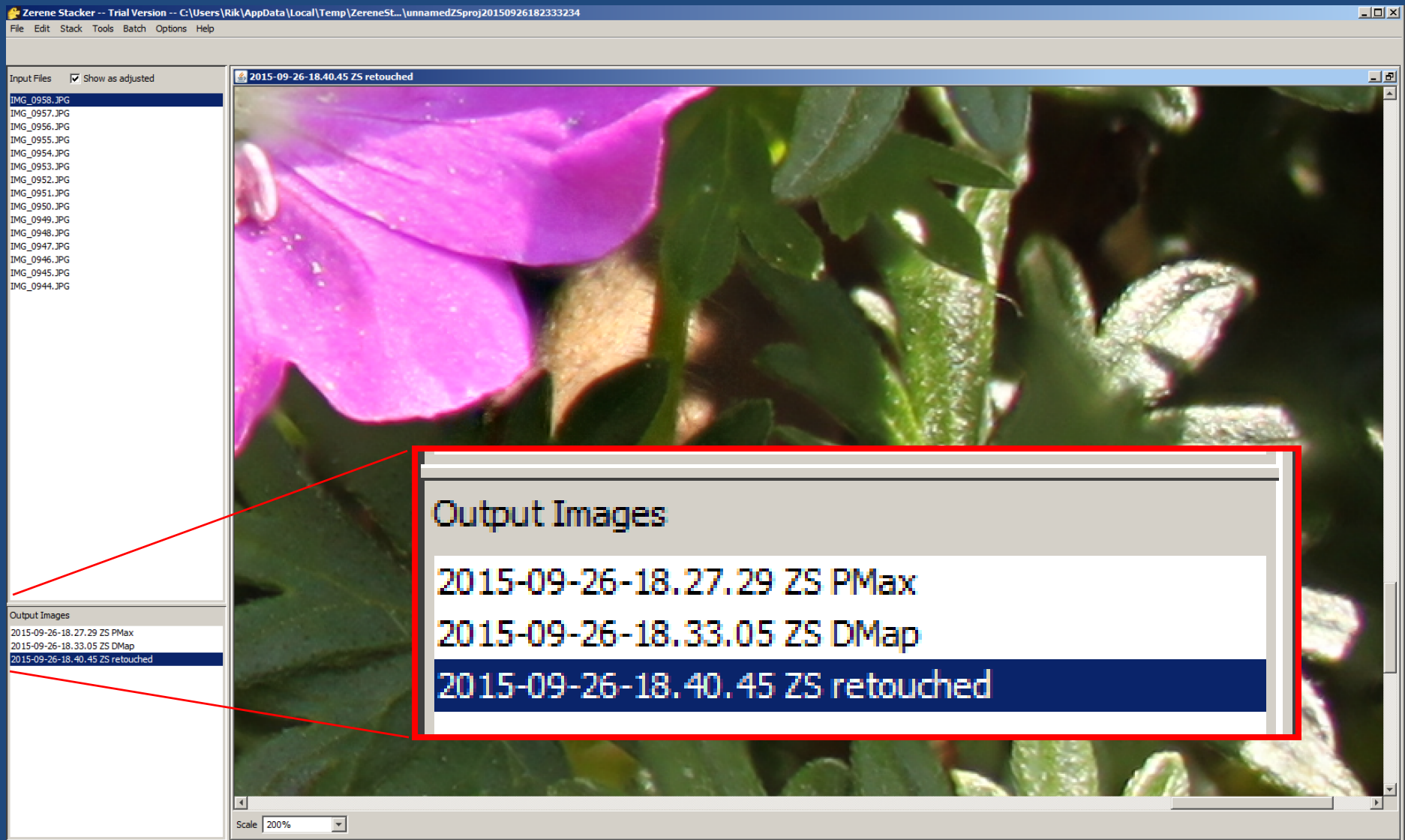


Processing in Zerene Stacker

DMap after retouching

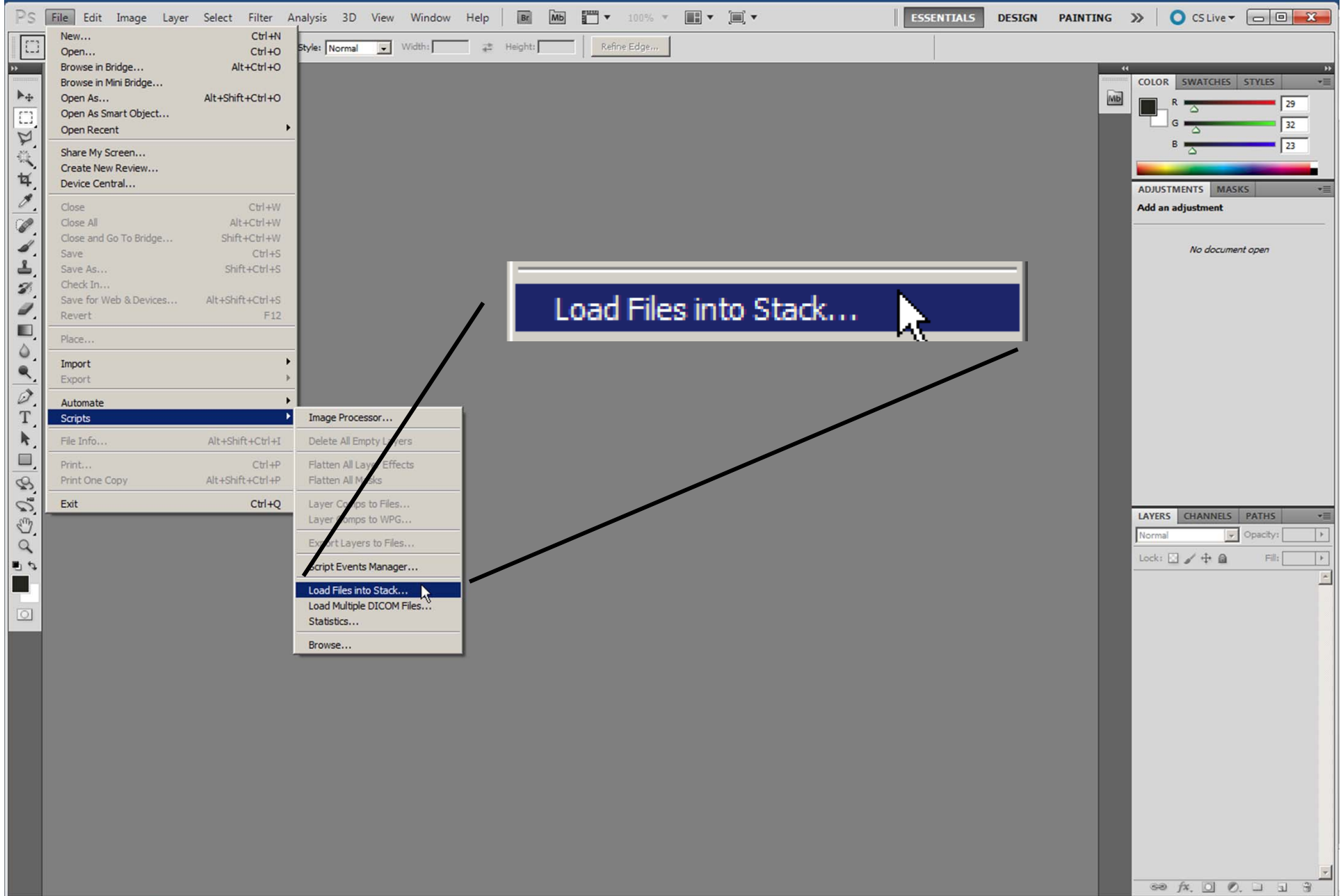


Processing in Zerene Stacker

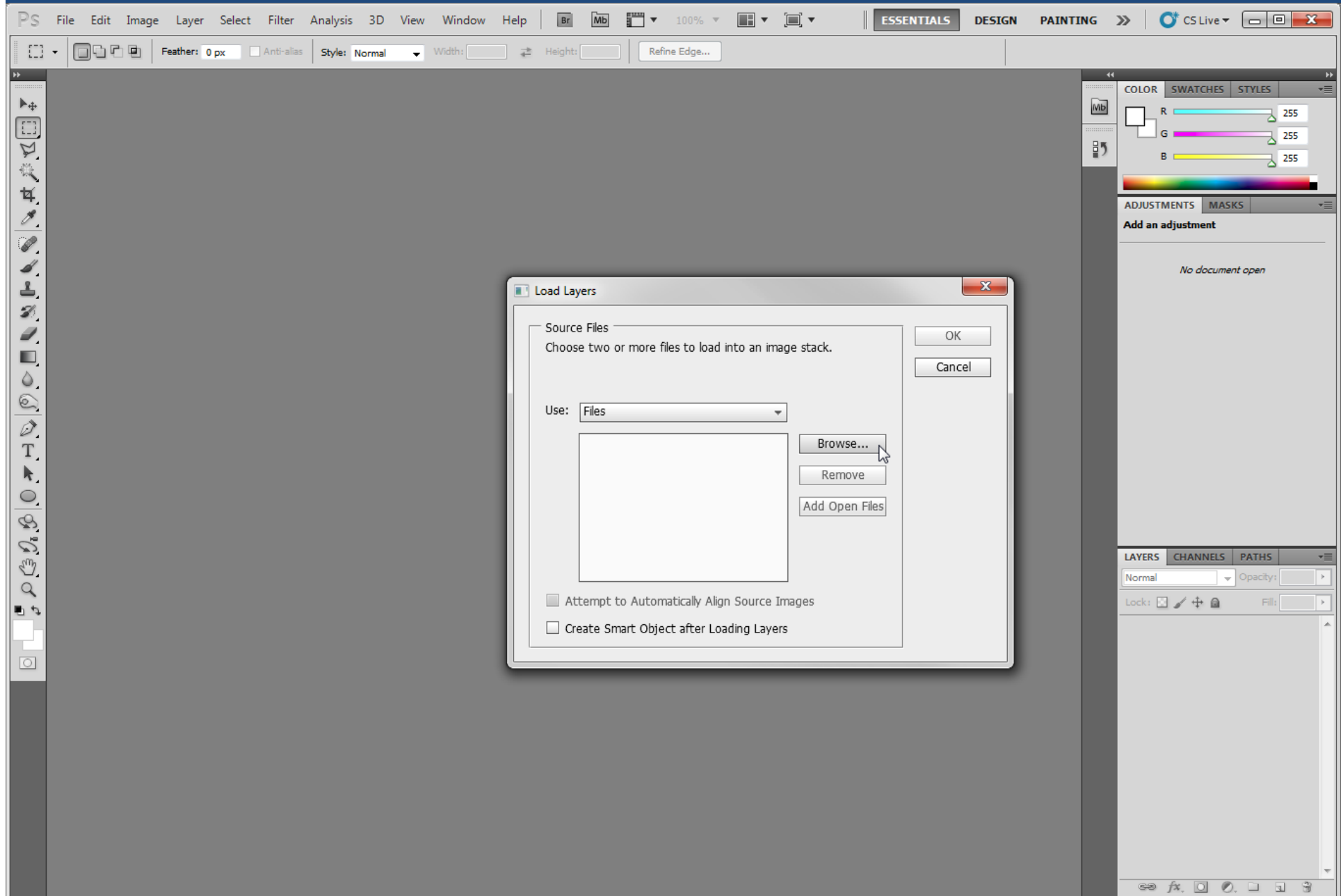


Stacking In Photoshop

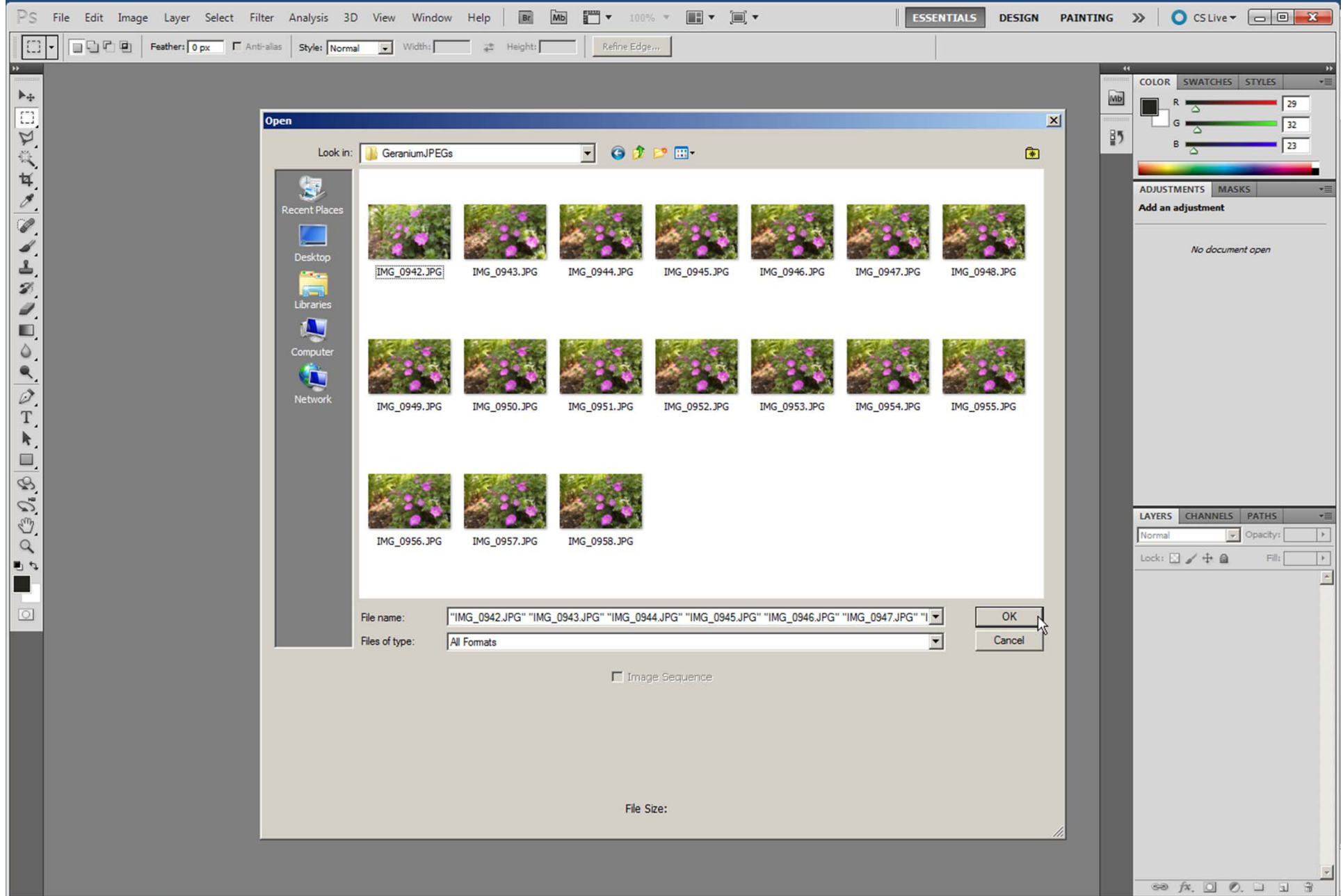
Stacking In Photoshop



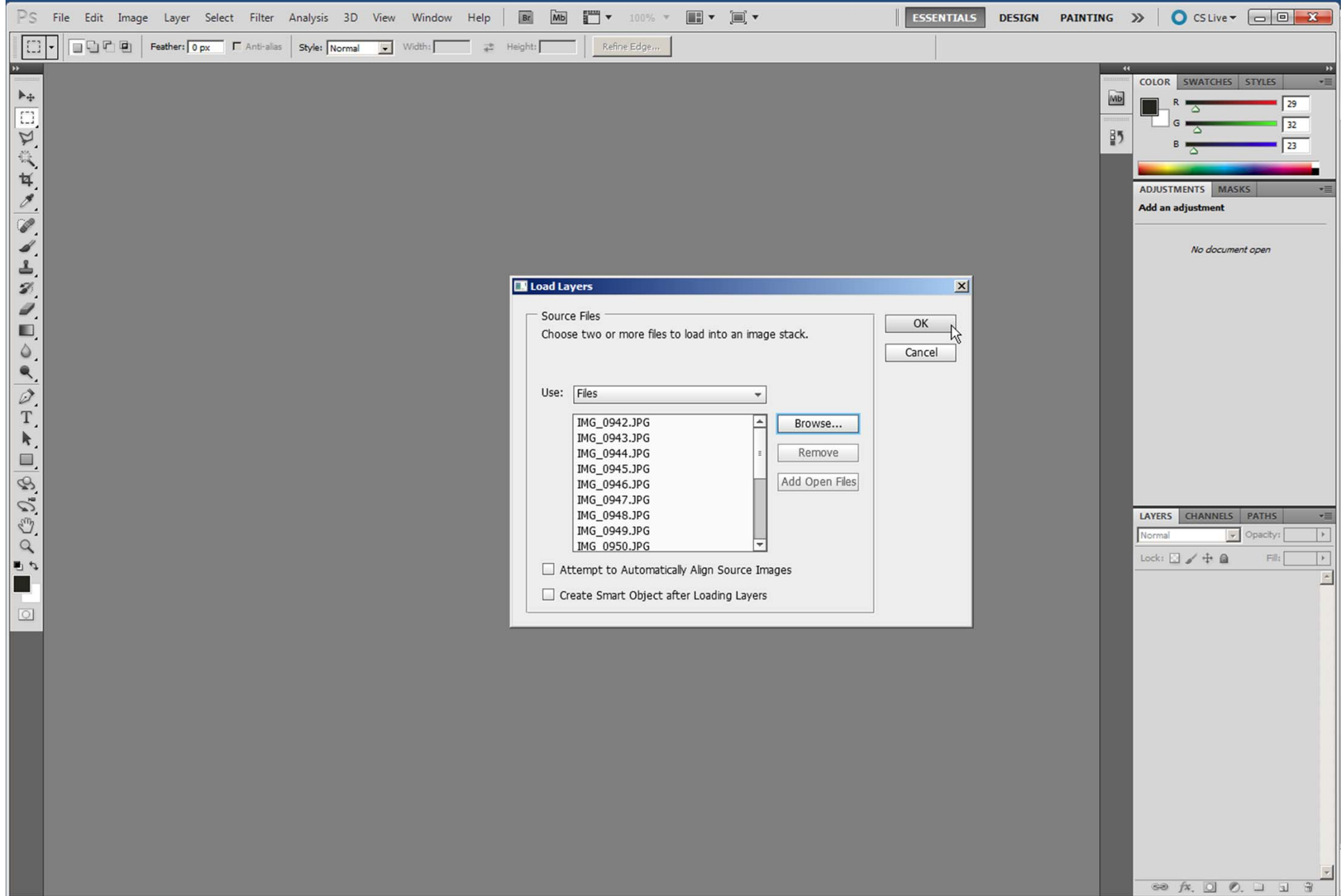
Stacking In Photoshop



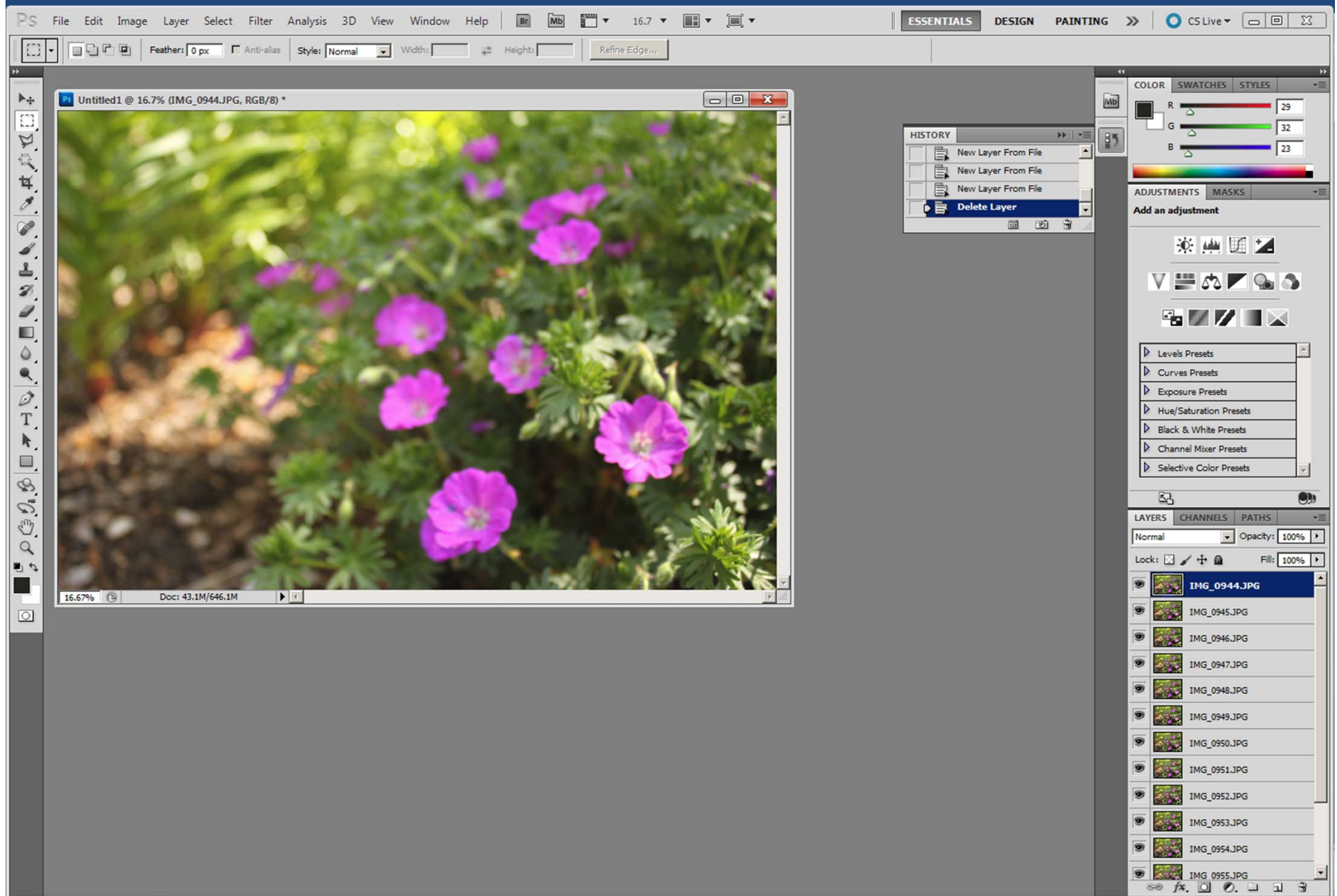
Stacking In Photoshop



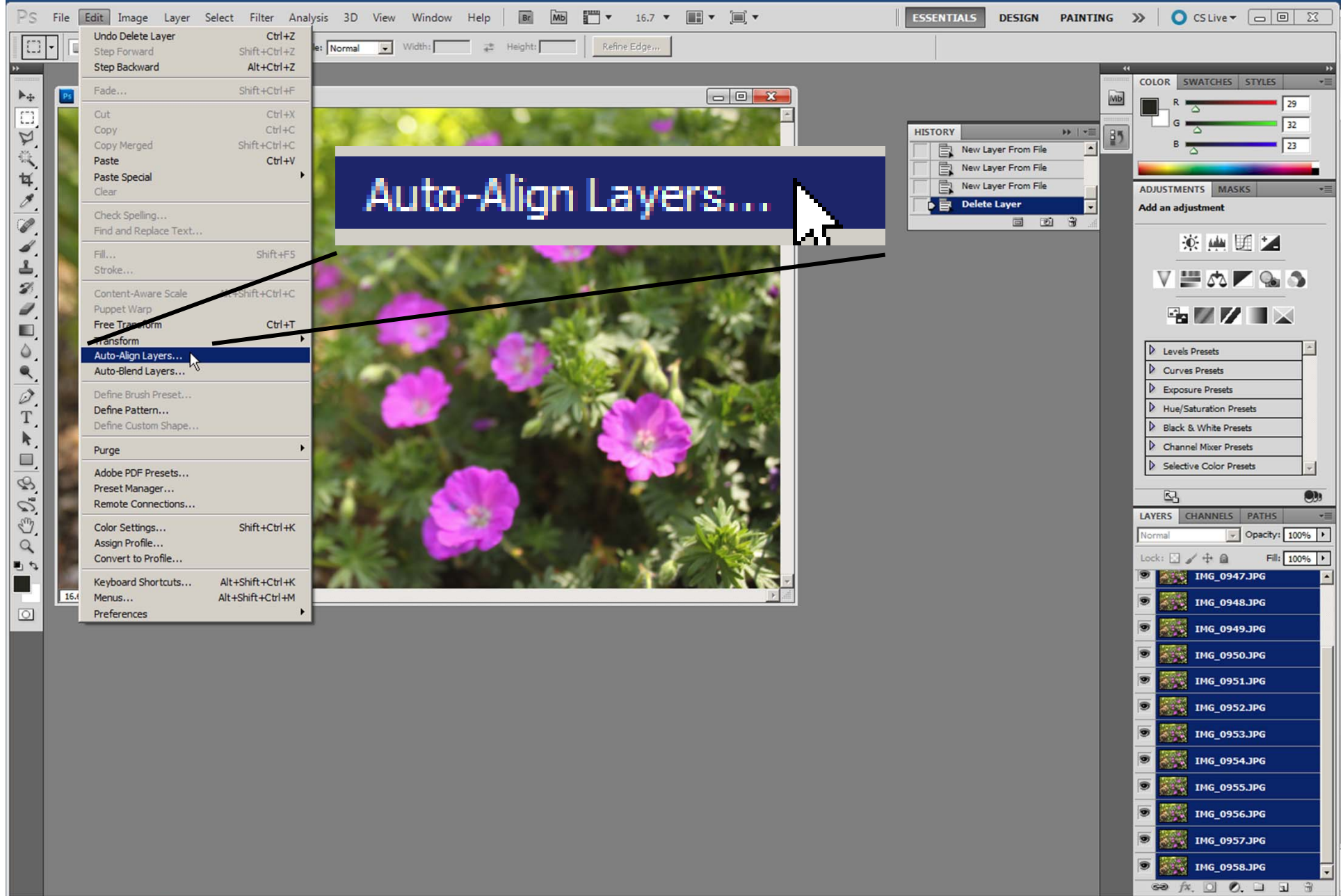
Stacking In Photoshop



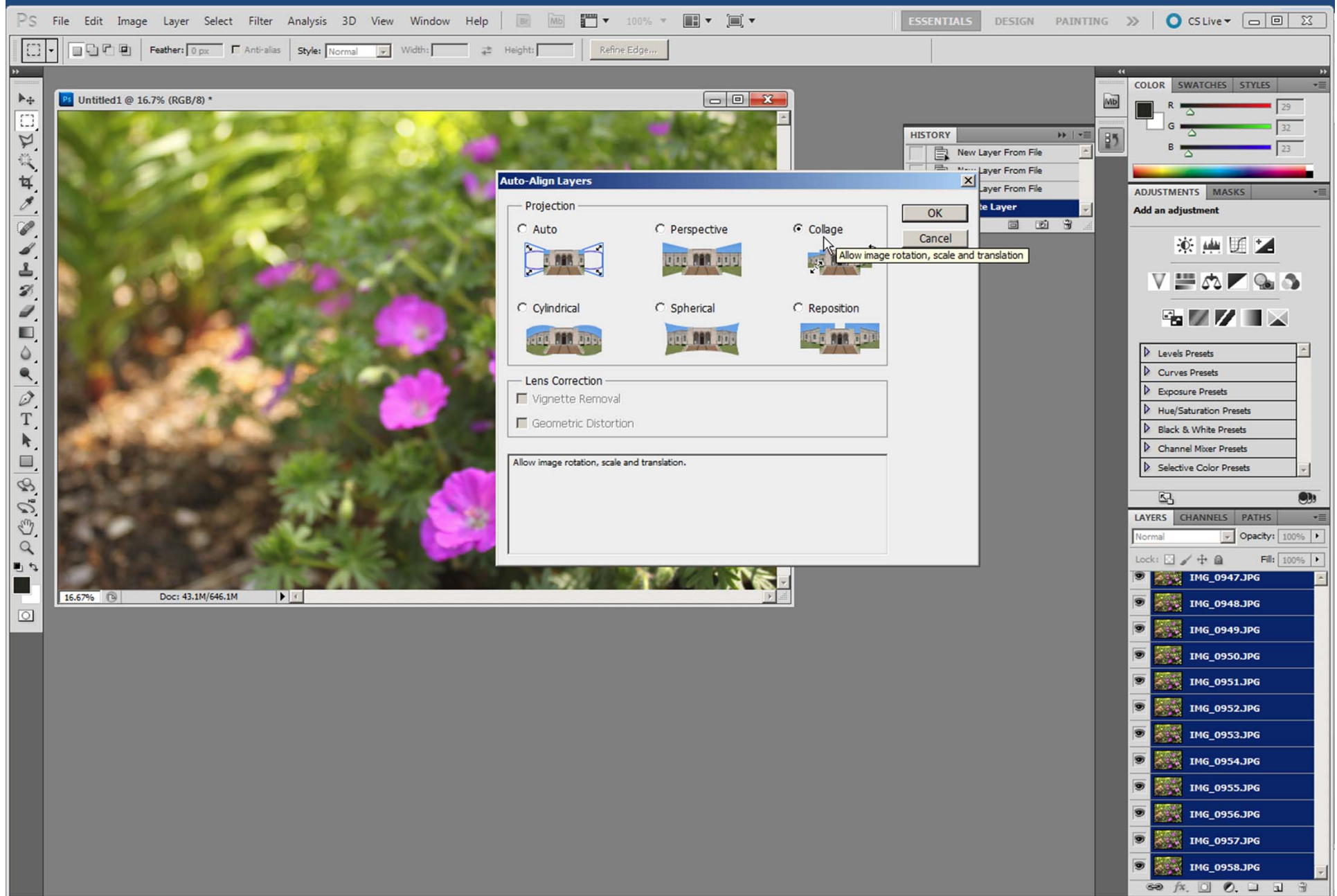
Stacking In Photoshop



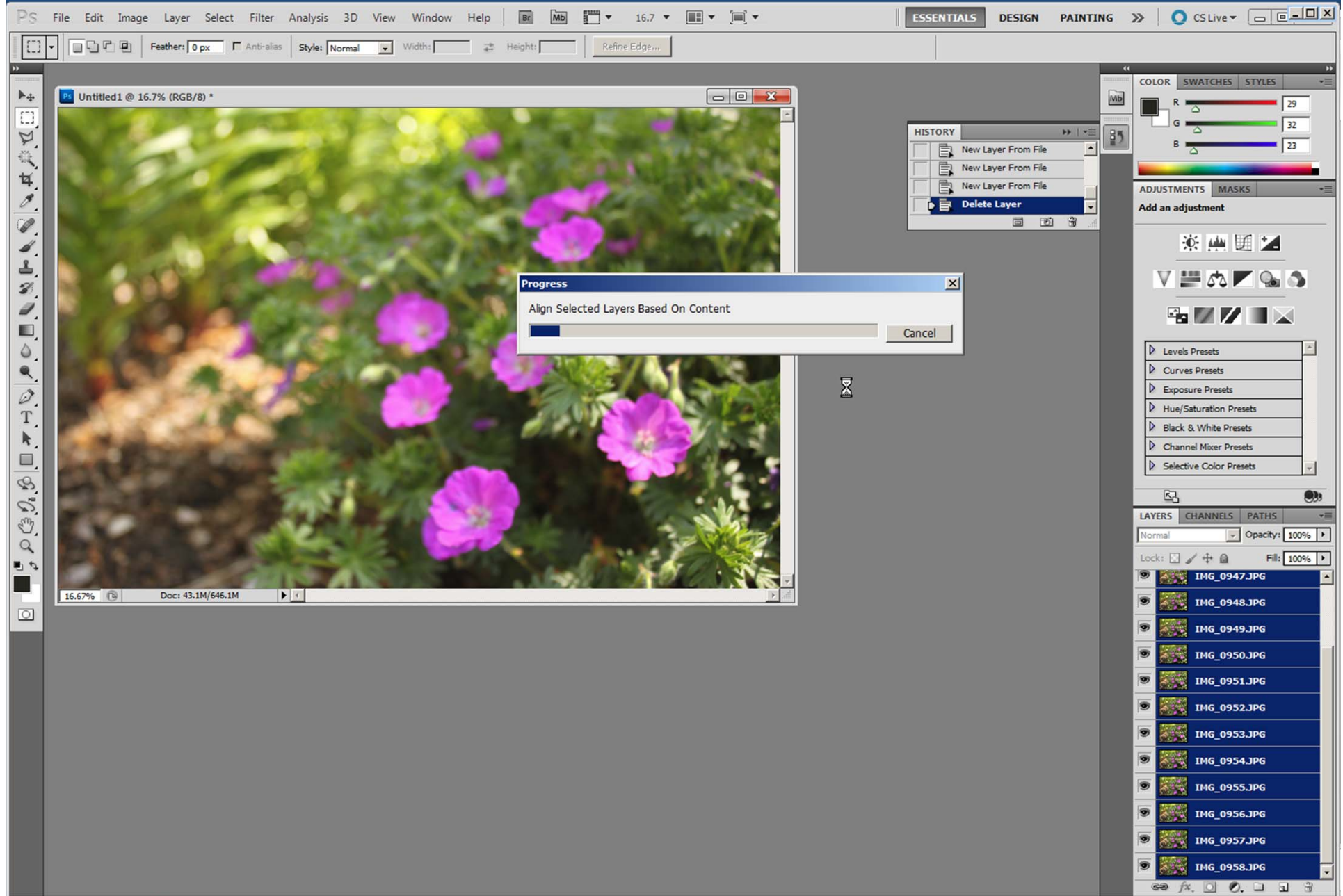
Stacking In Photoshop



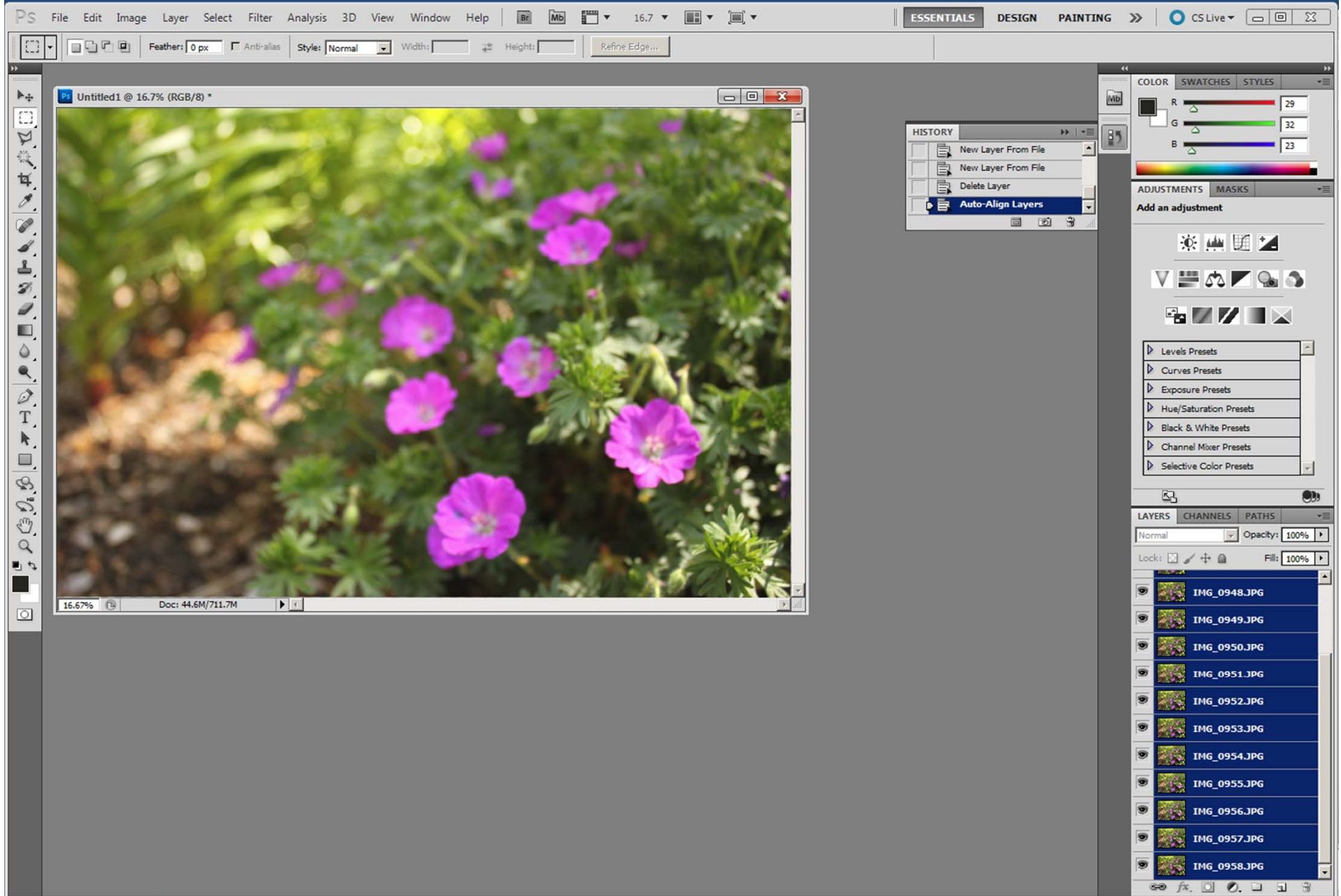
Stacking In Photoshop



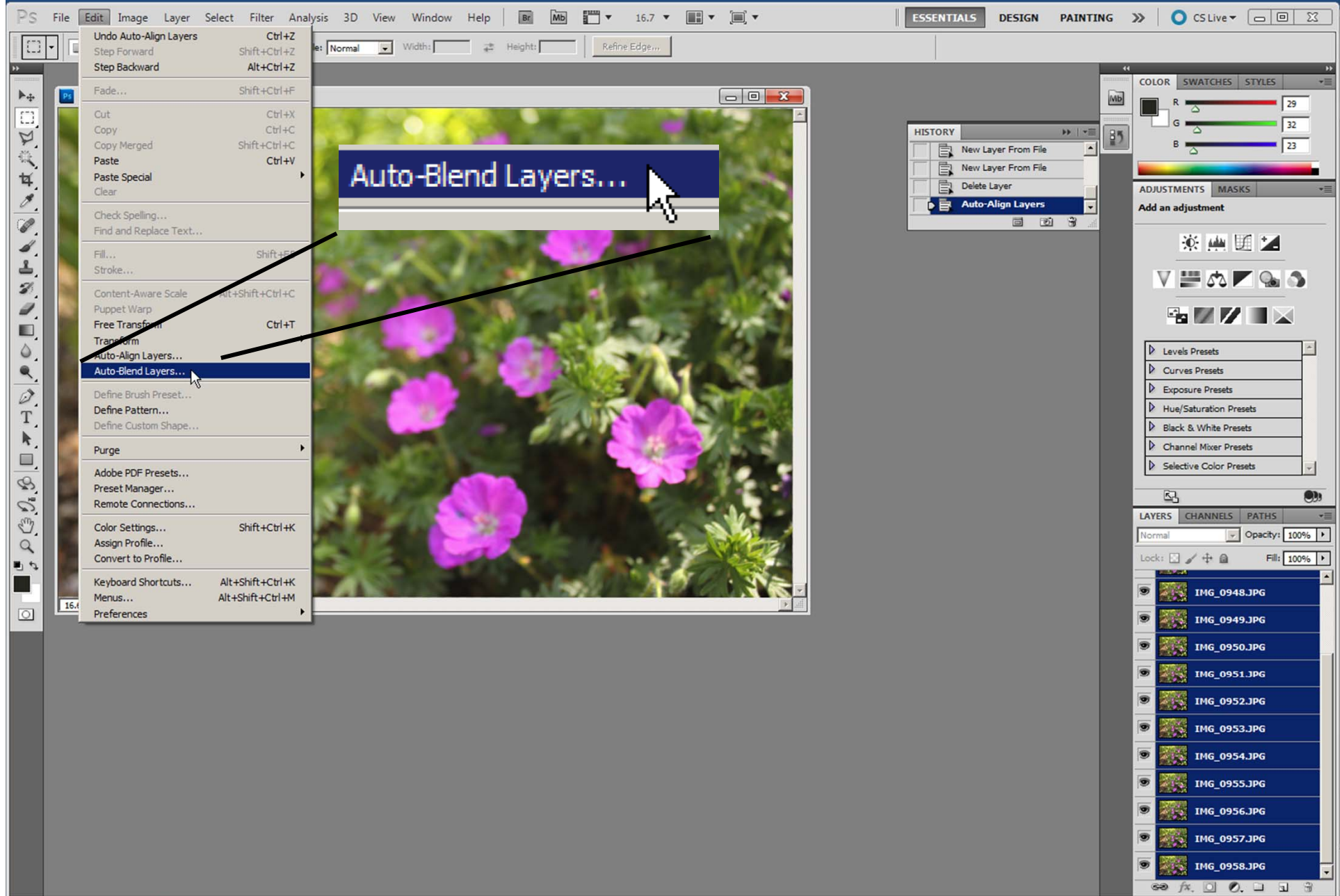
Stacking In Photoshop



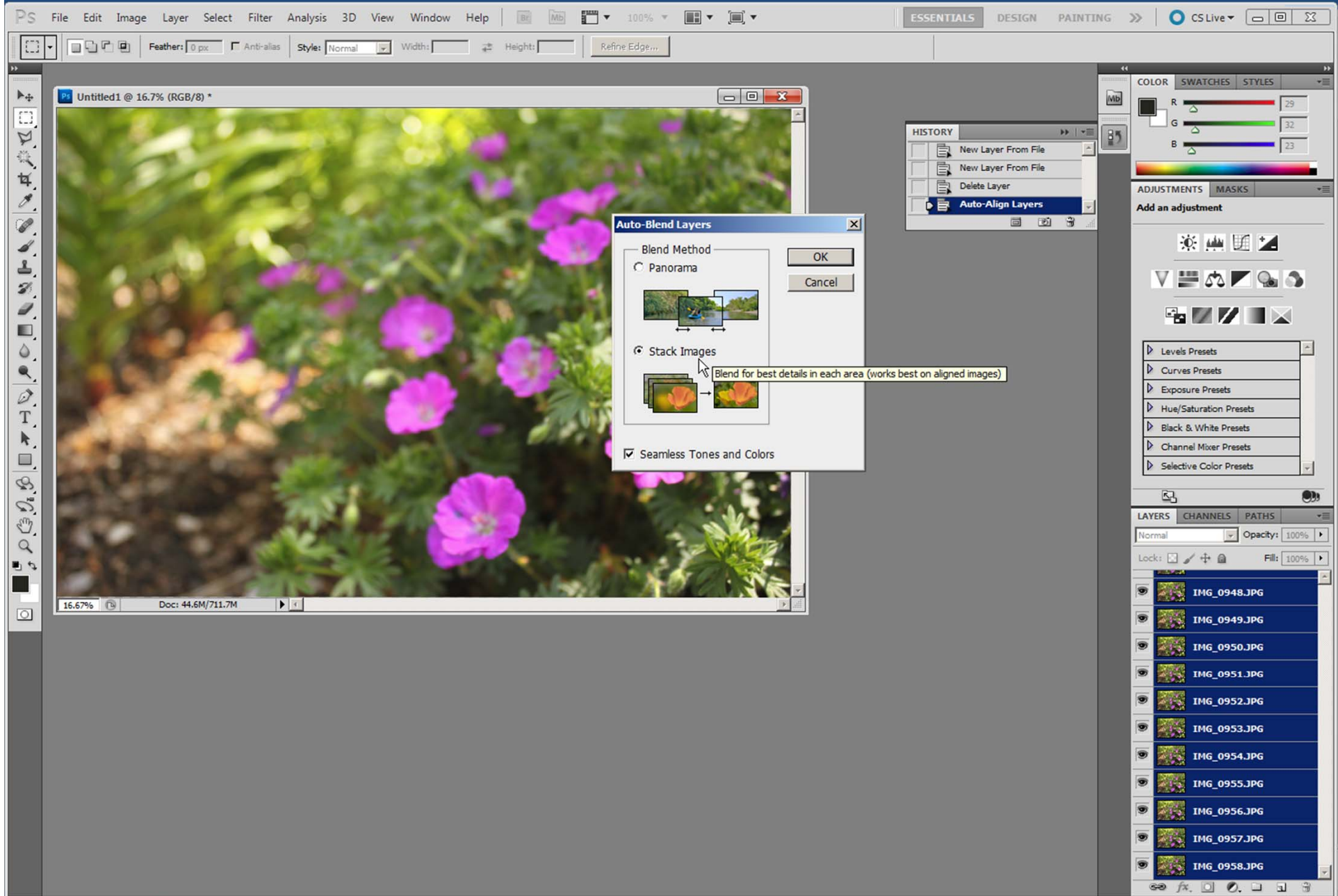
Stacking In Photoshop



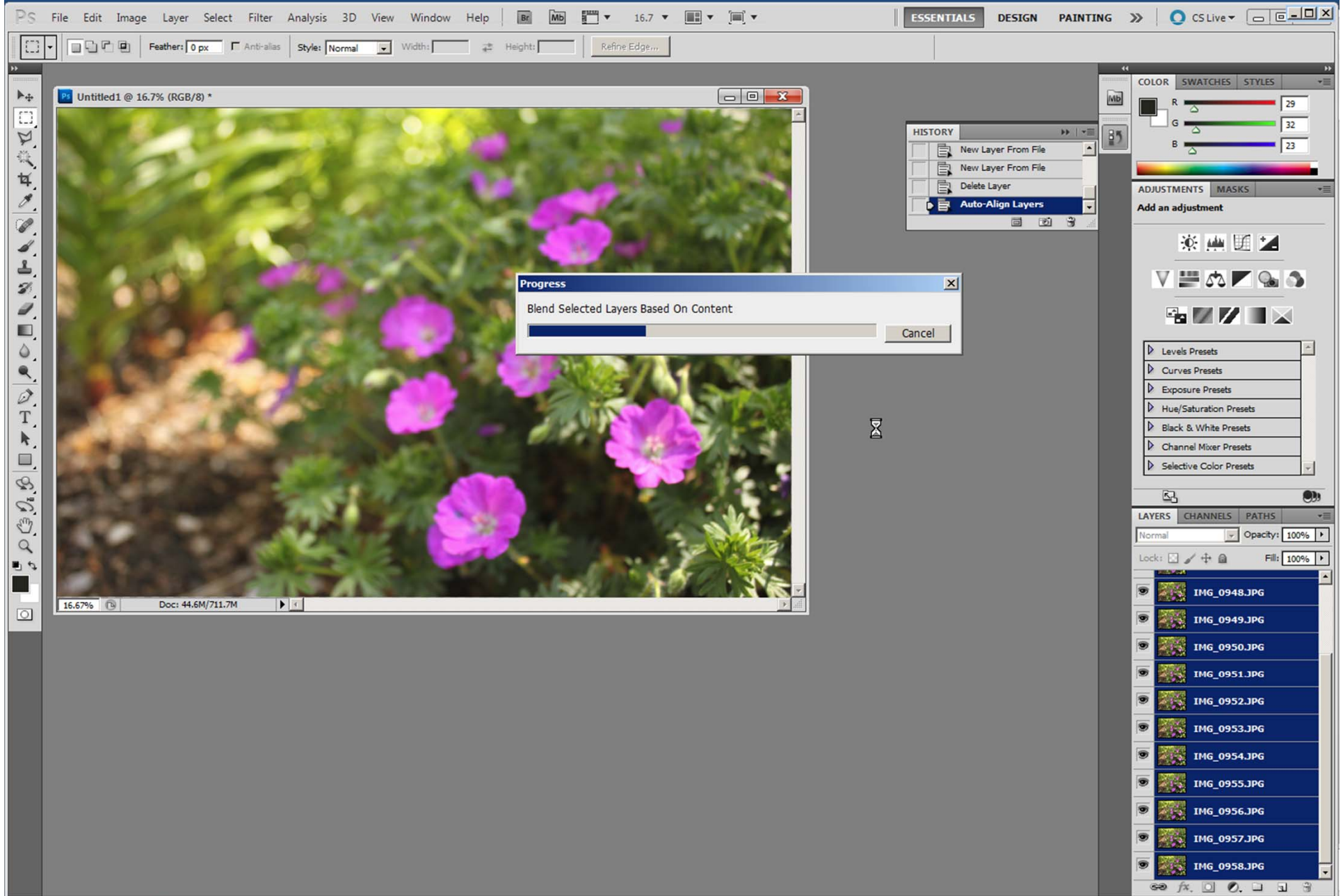
Stacking In Photoshop



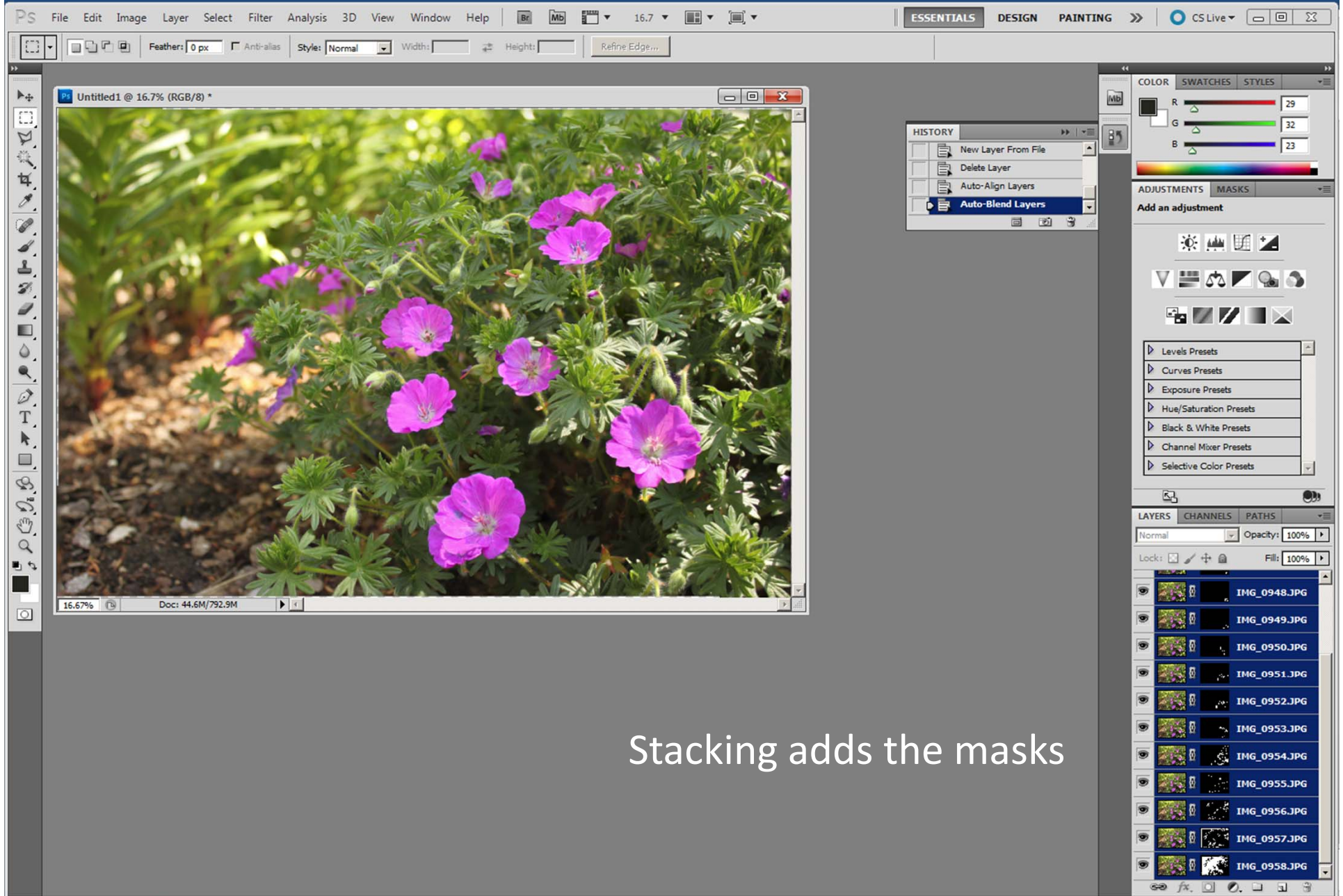
Stacking In Photoshop



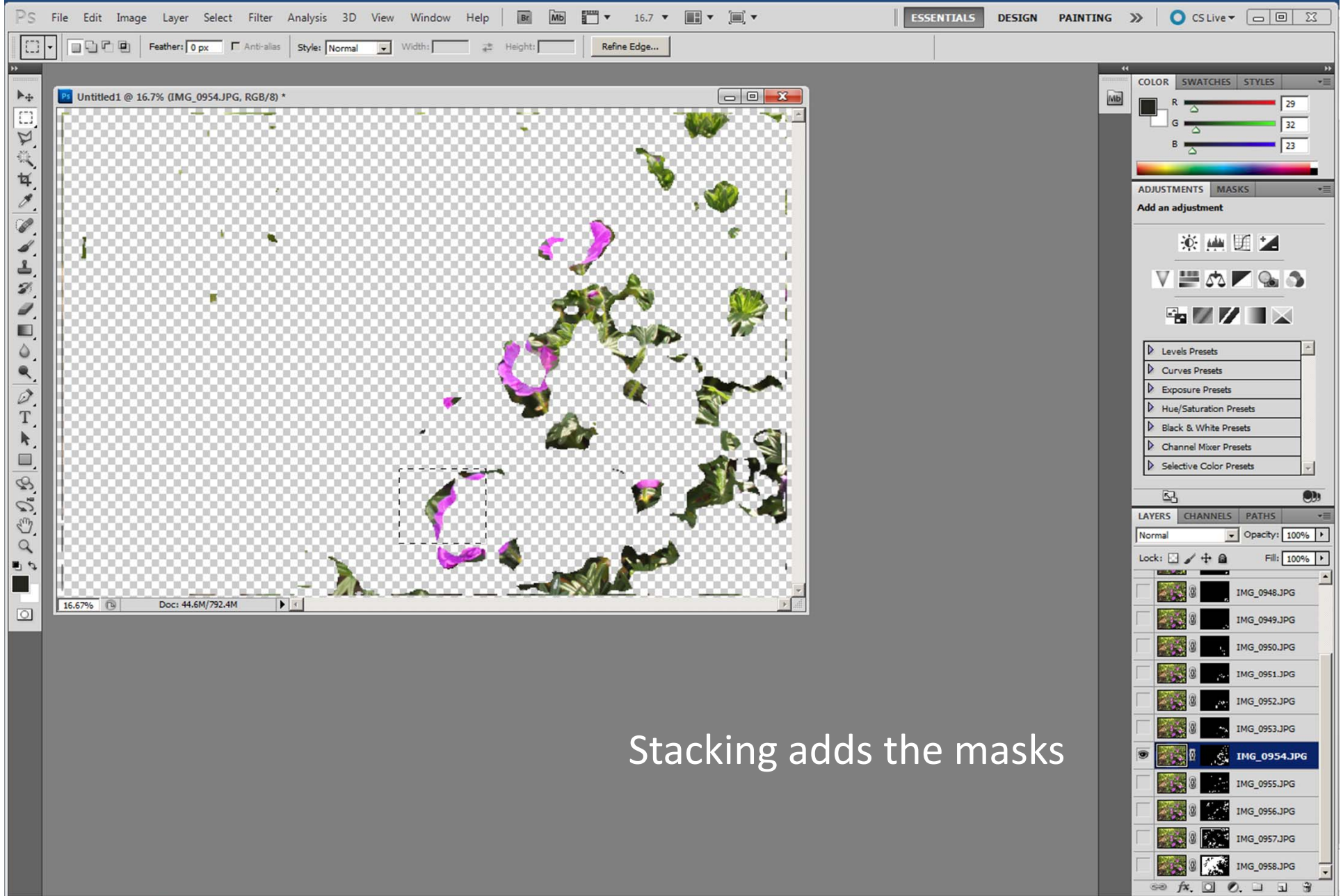
Stacking In Photoshop



Stacking In Photoshop

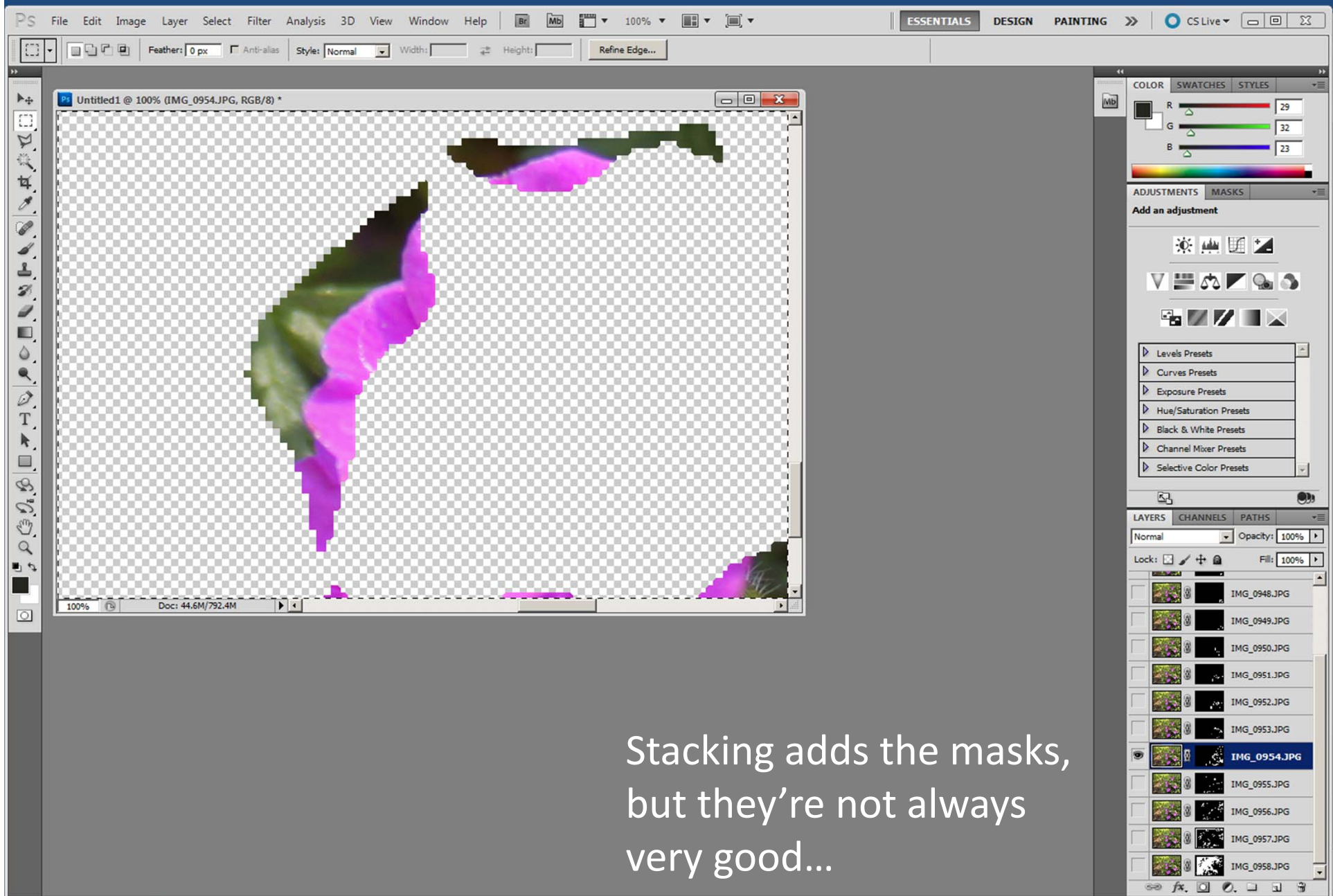


Stacking In Photoshop



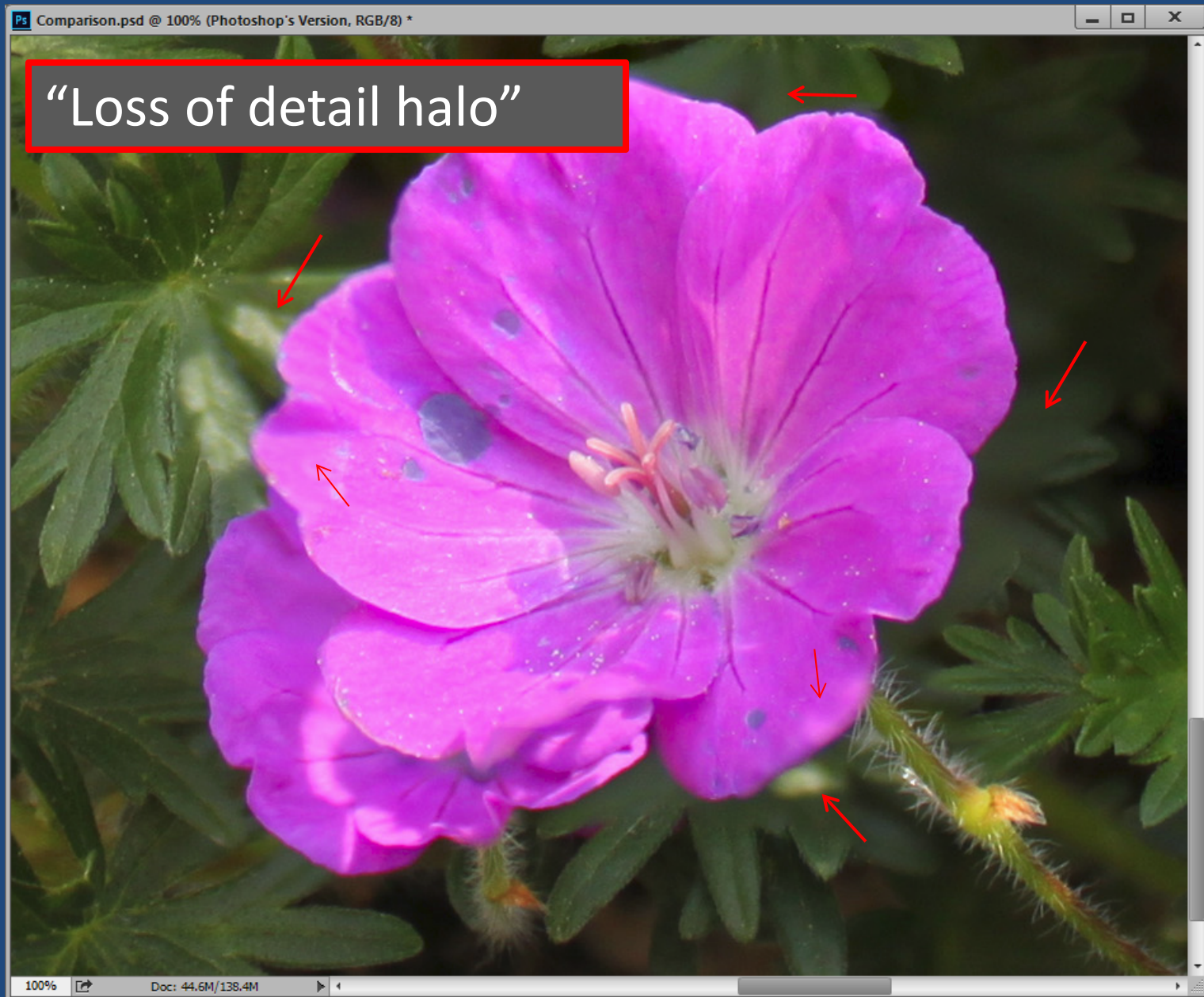
Stacking adds the masks

Stacking In Photoshop

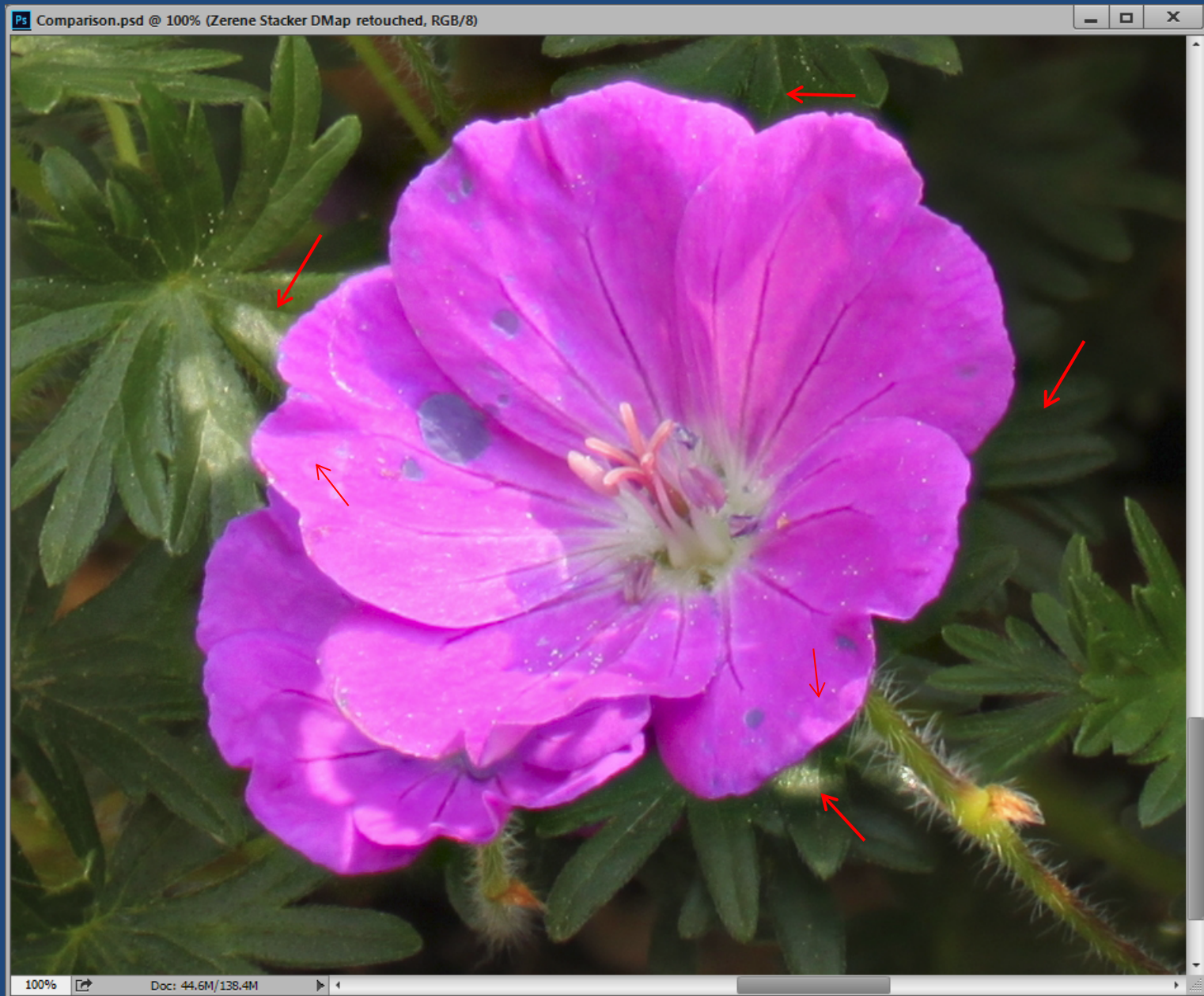


Stacking adds the masks,
but they're not always
very good...

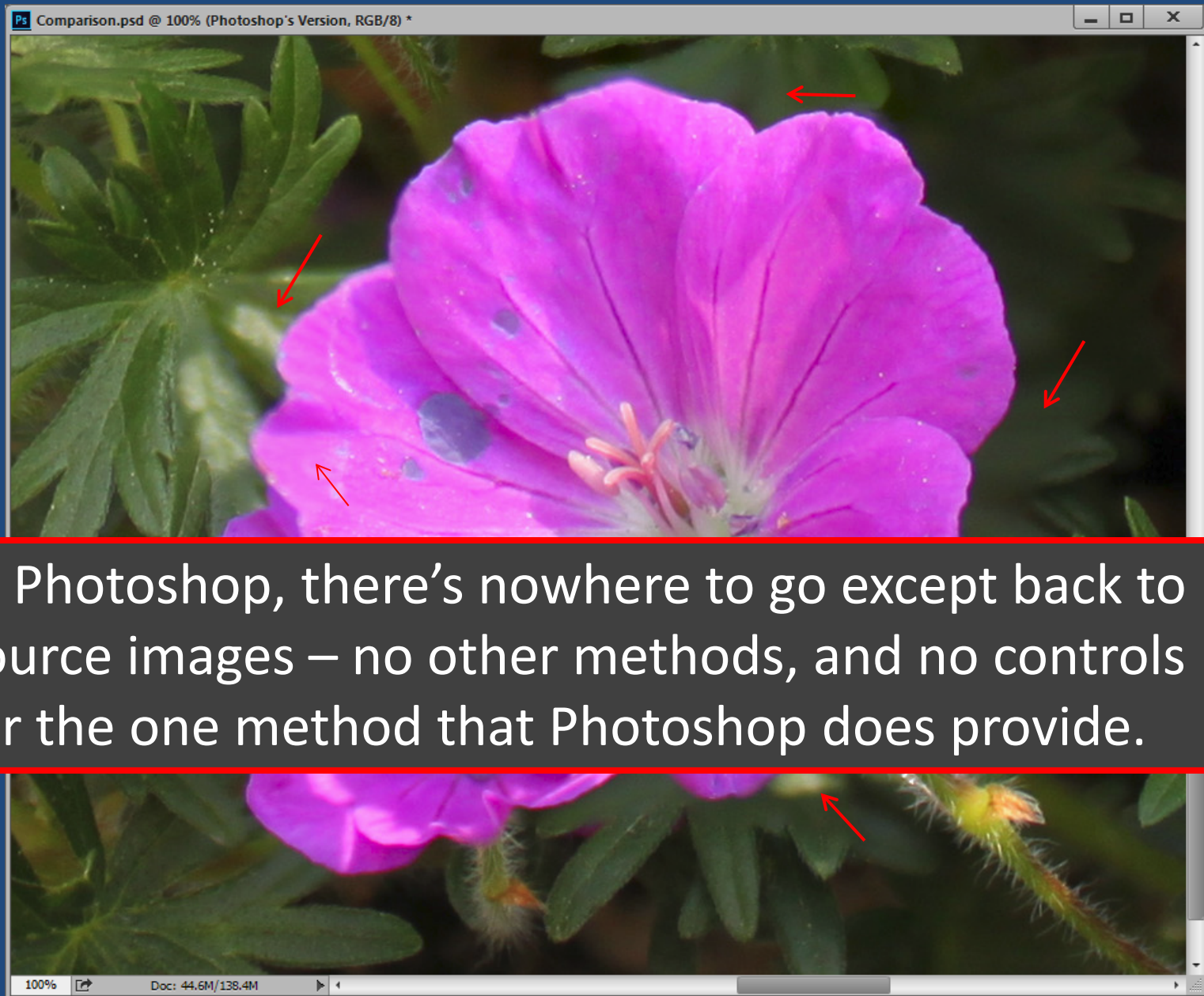
Details by Photoshop



Details by Zerene Stacker



Details by Photoshop



In Photoshop, there's nowhere to go except back to source images – no other methods, and no controls for the one method that Photoshop does provide.

What Problems Appear in “Good” Stacks?

- Edge streaks
- Defect trails
- Transparent foreground
- Halos
 - Loss of detail (already saw this)
 - Dark/light bands in uniform background

Edge Streaks

Cause: inconsistent framing – usually handheld stacks or wobbly setups

Solution: shoot wider & crop, sometimes can retouch from source image



Defect Trails

Cause: sensor dust (dark) or warm pixels (bright)

Solutions: 1) clean the sensor, 2) use shorter exposure with more light, 3) remove spots or trails with retouching or healing brush.

One Source Image



Stacked Result



This Stack Is Surprisingly Difficult

It looks so simple.

What could possibly go wrong?



The Individual Frames Still Look Simple

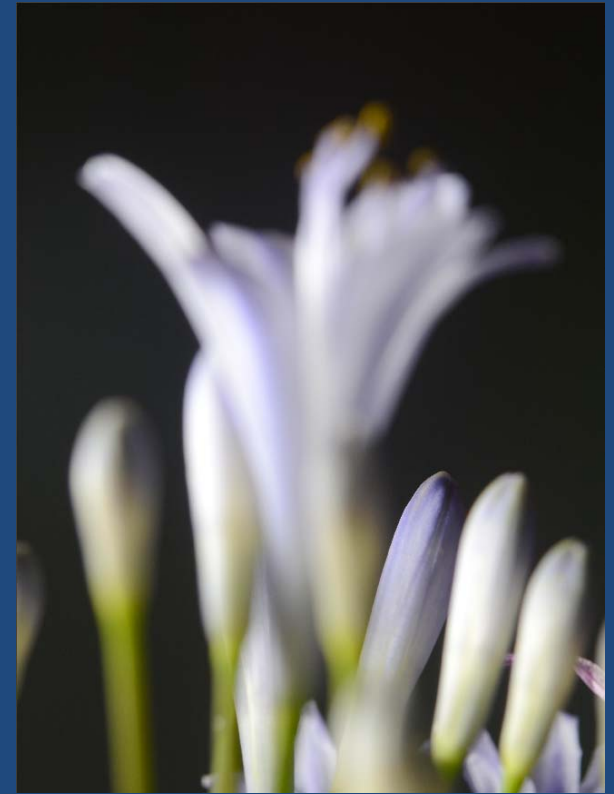
Front



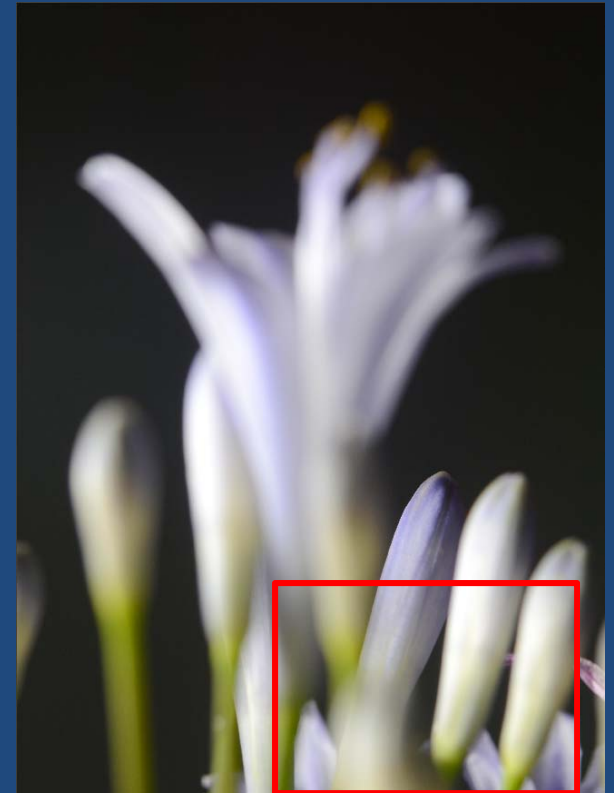
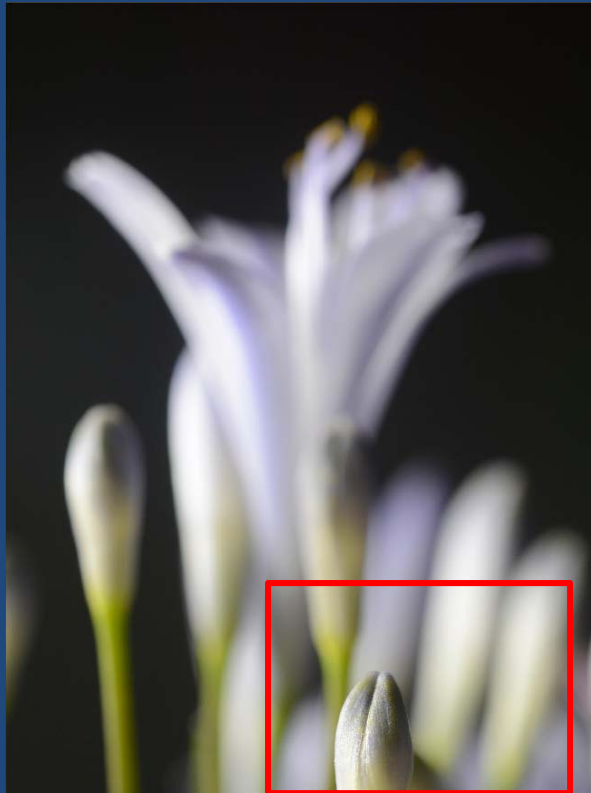
Middle



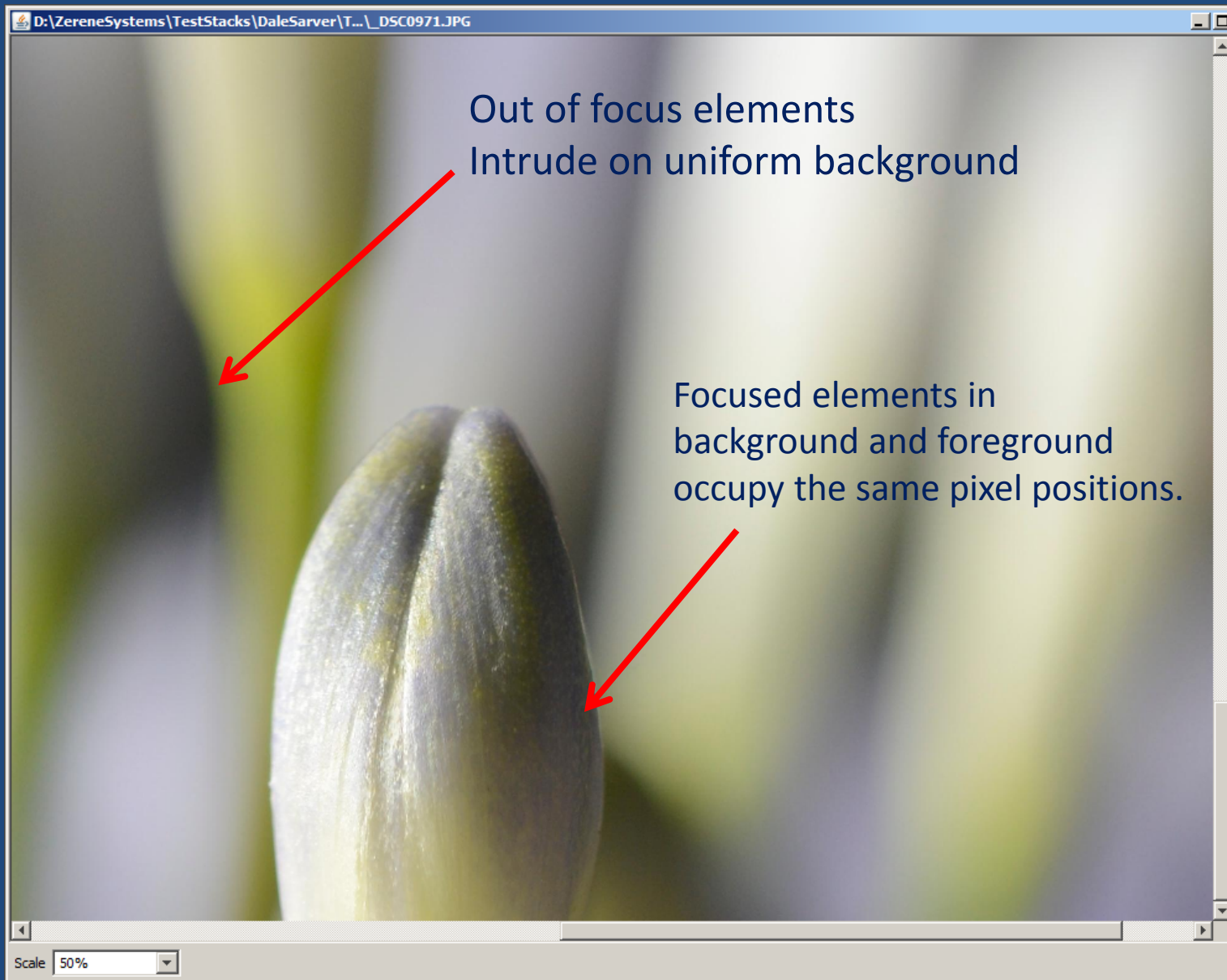
Back



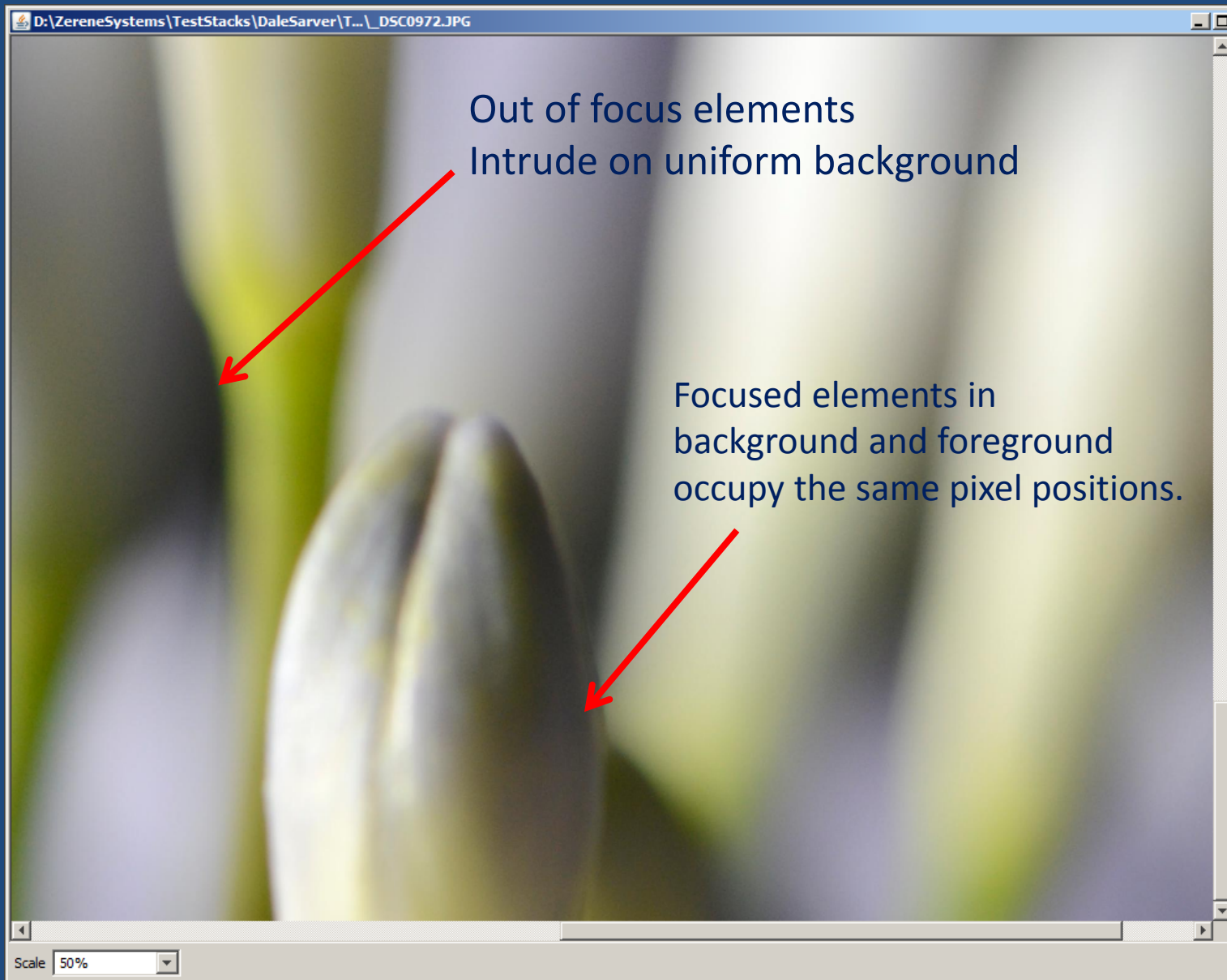
Let's Take a Closer Look



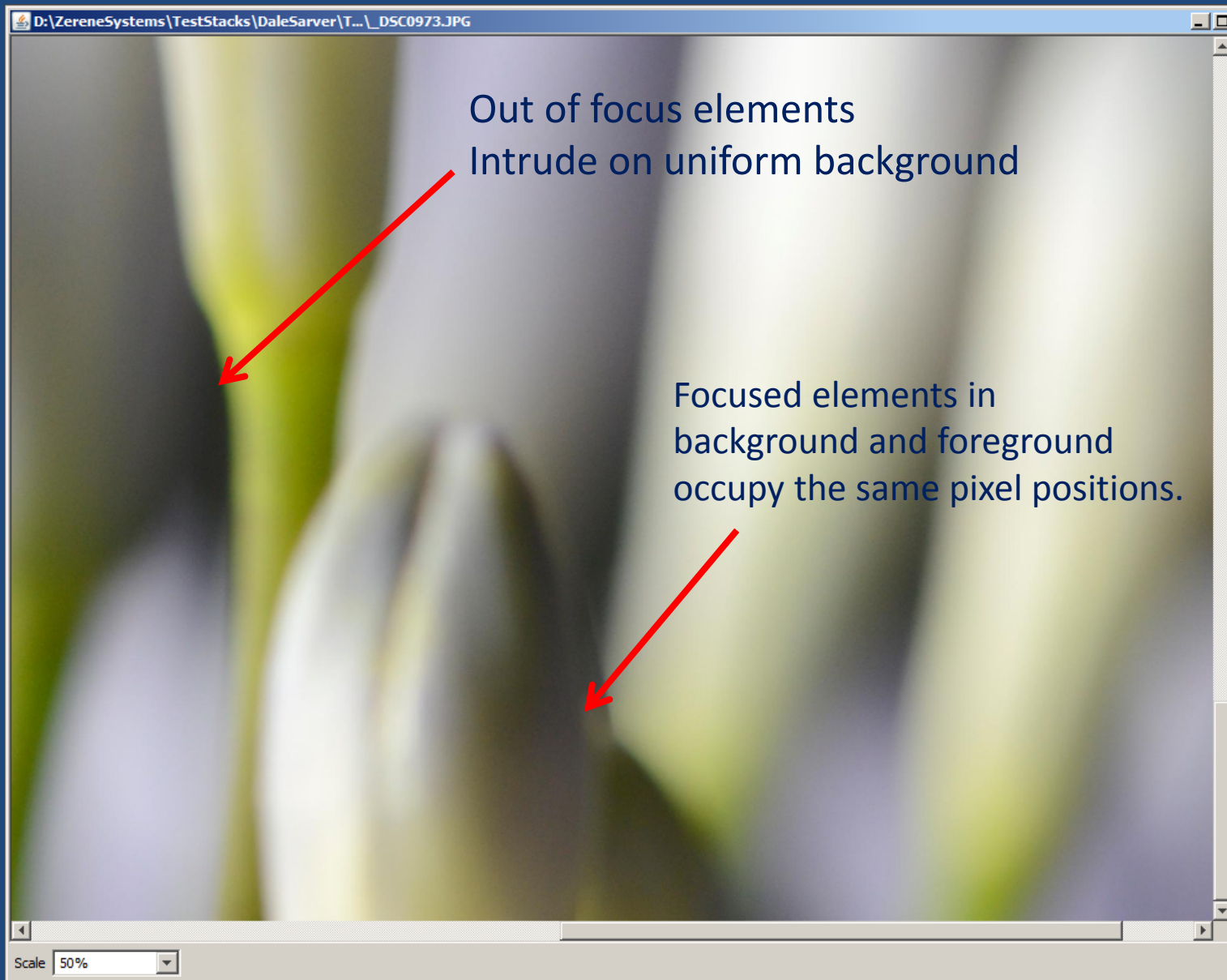
The Sequence Shows a Different Story



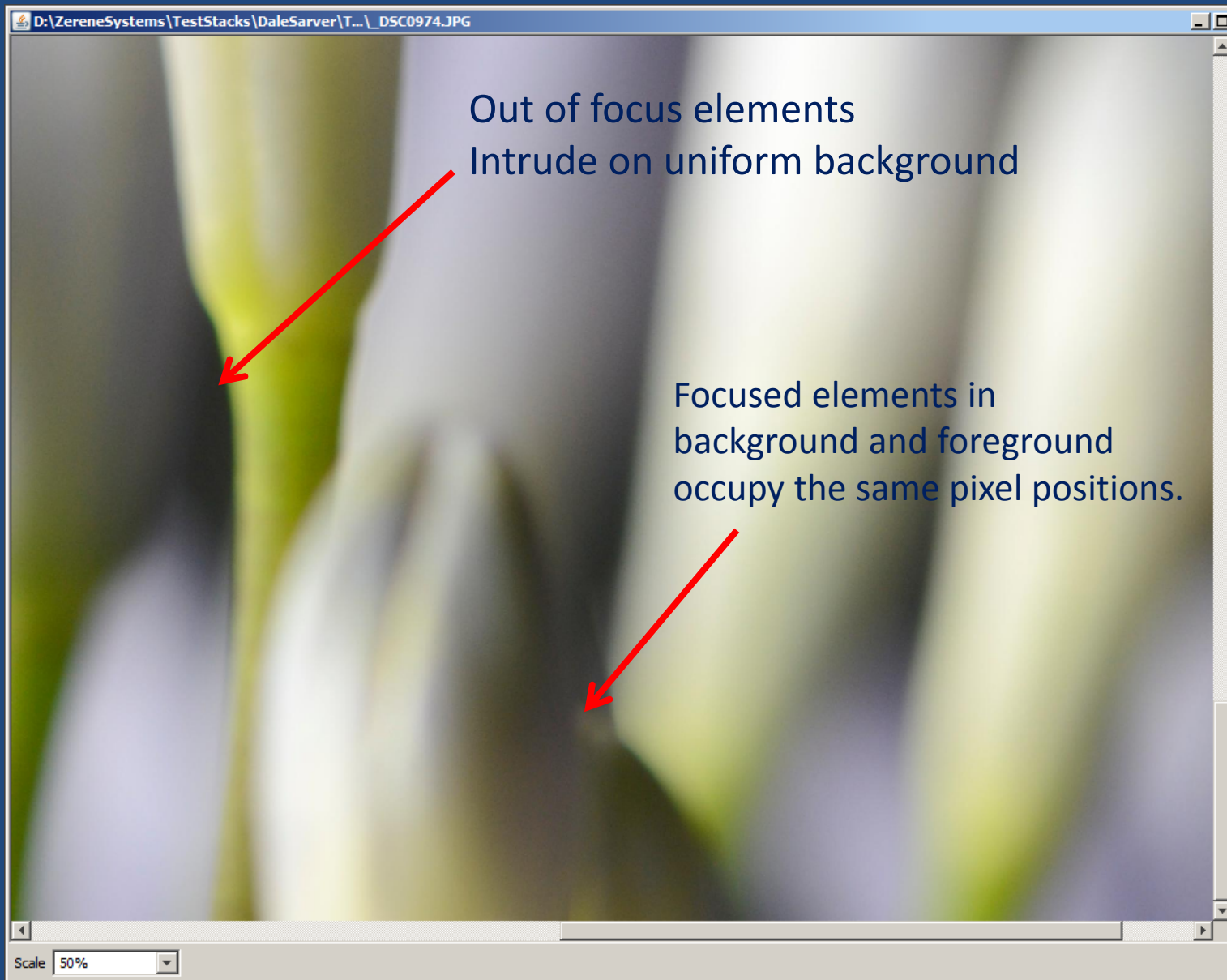
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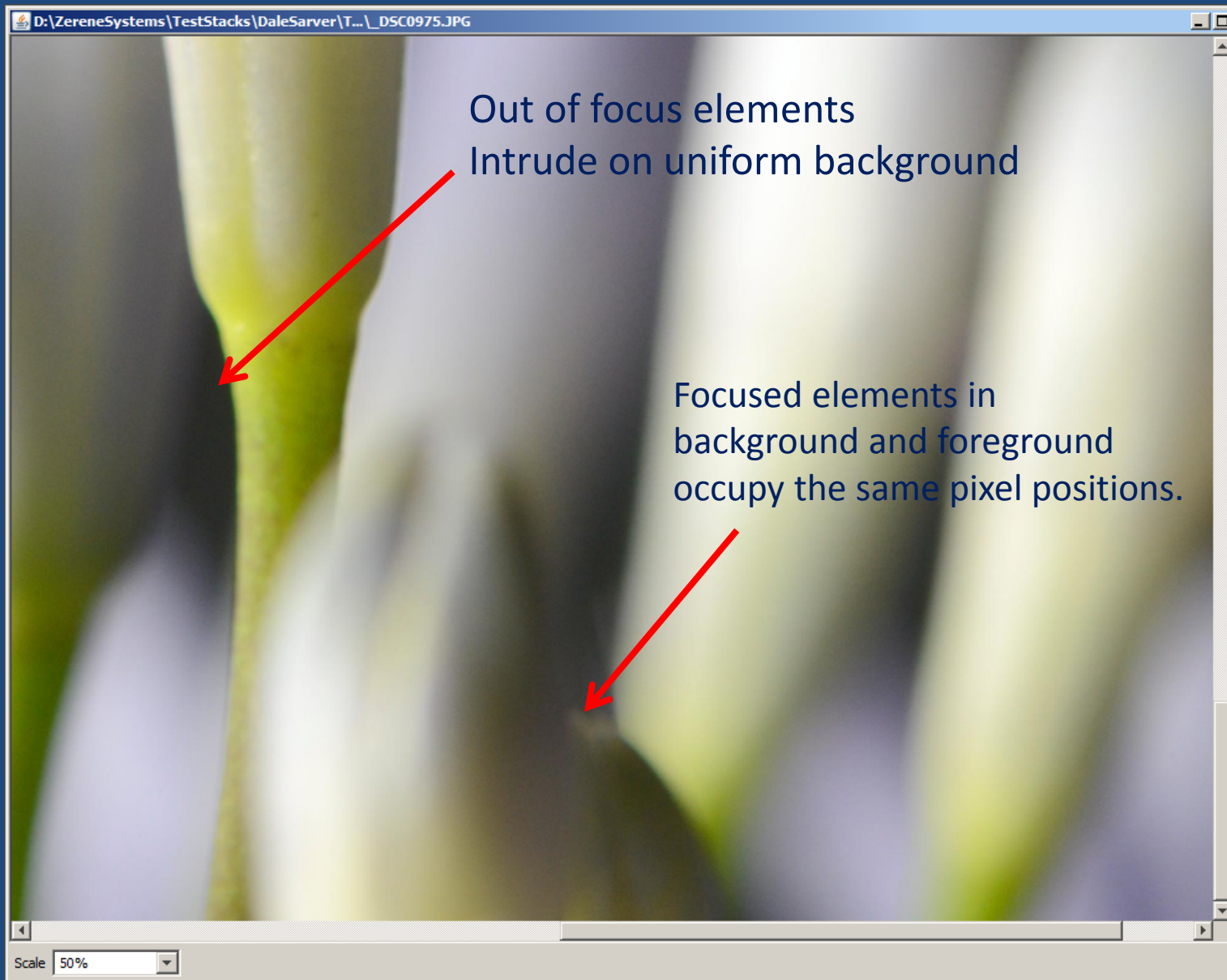
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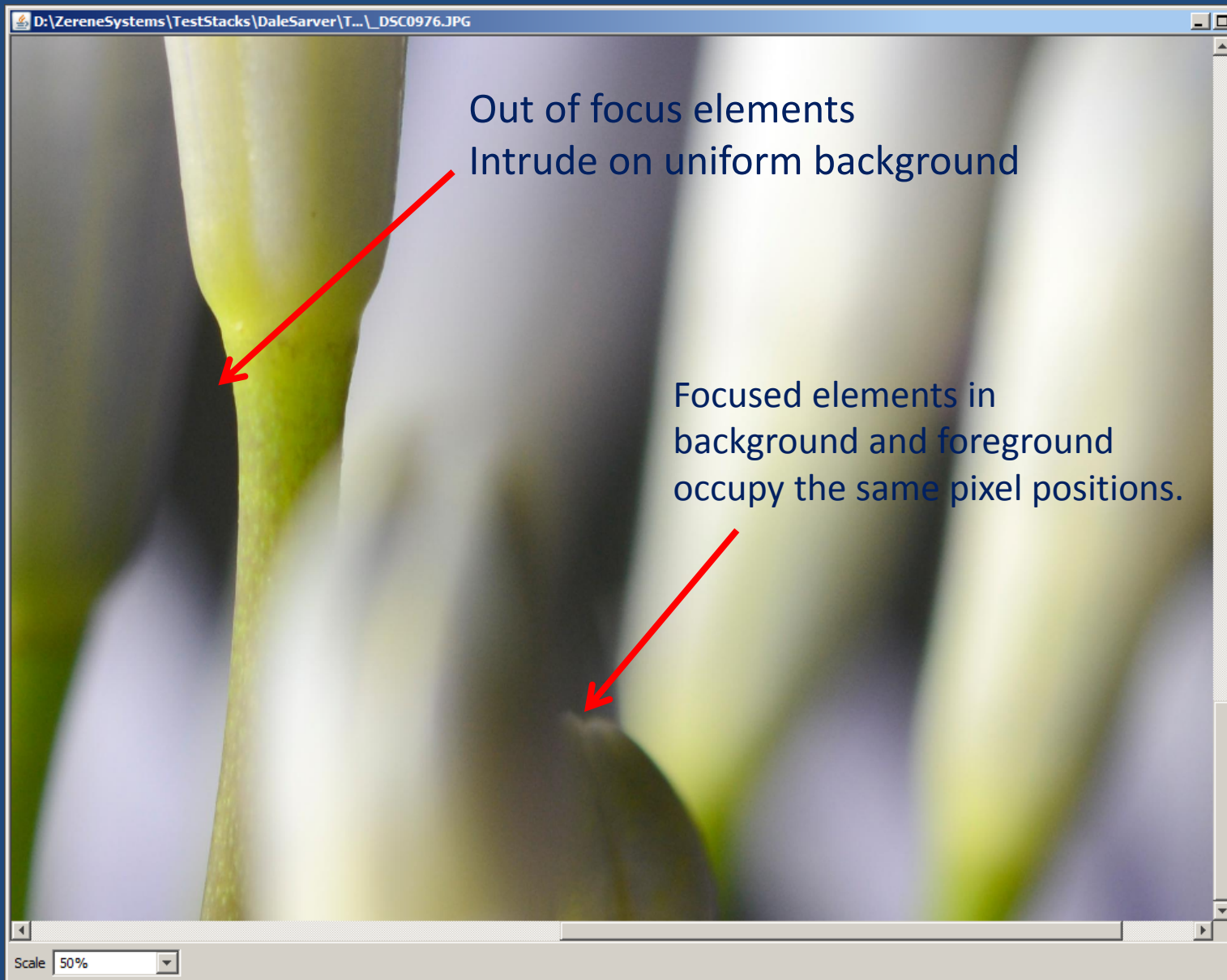
The Sequence Shows a Different Story



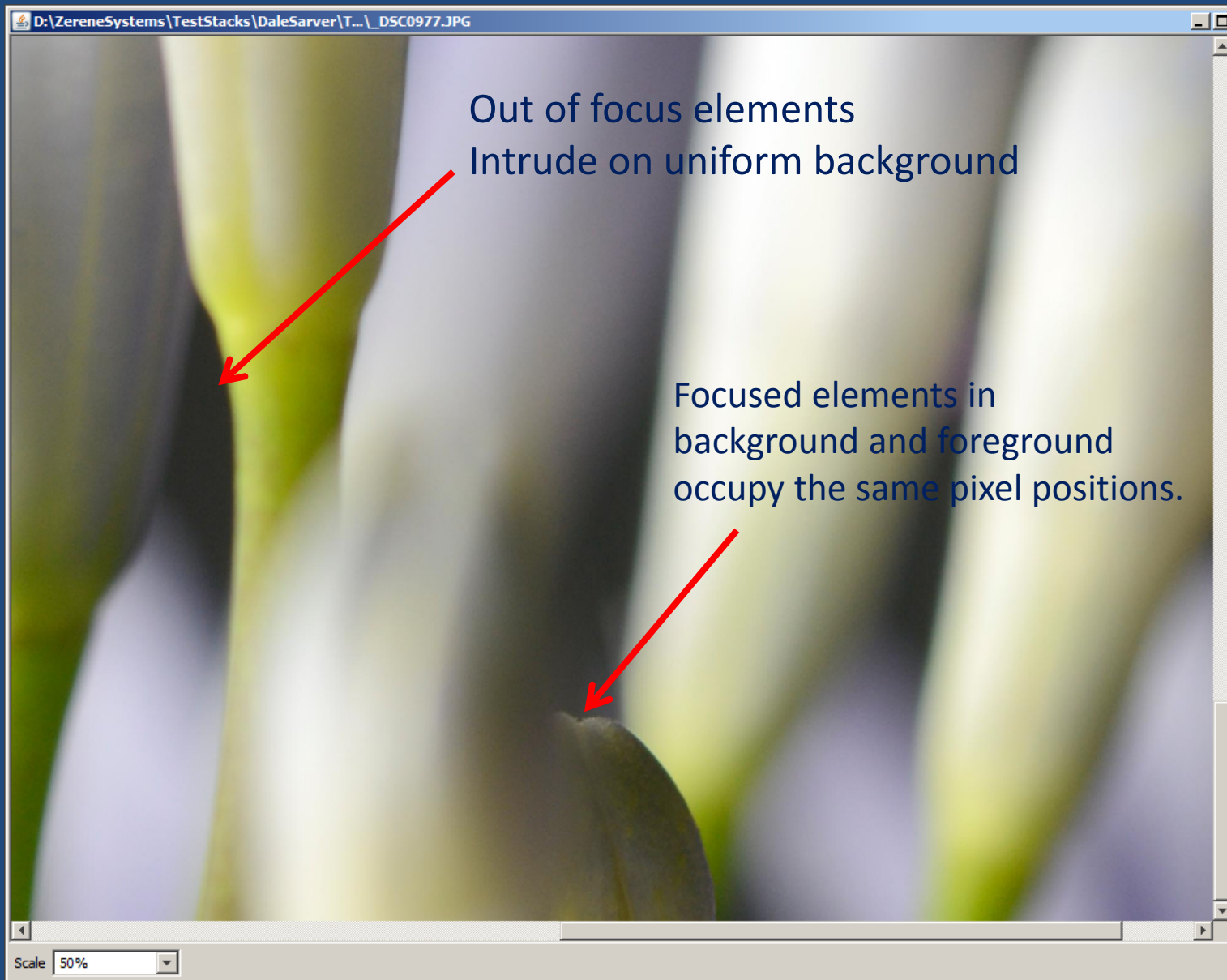
The Sequence Shows a Different Story



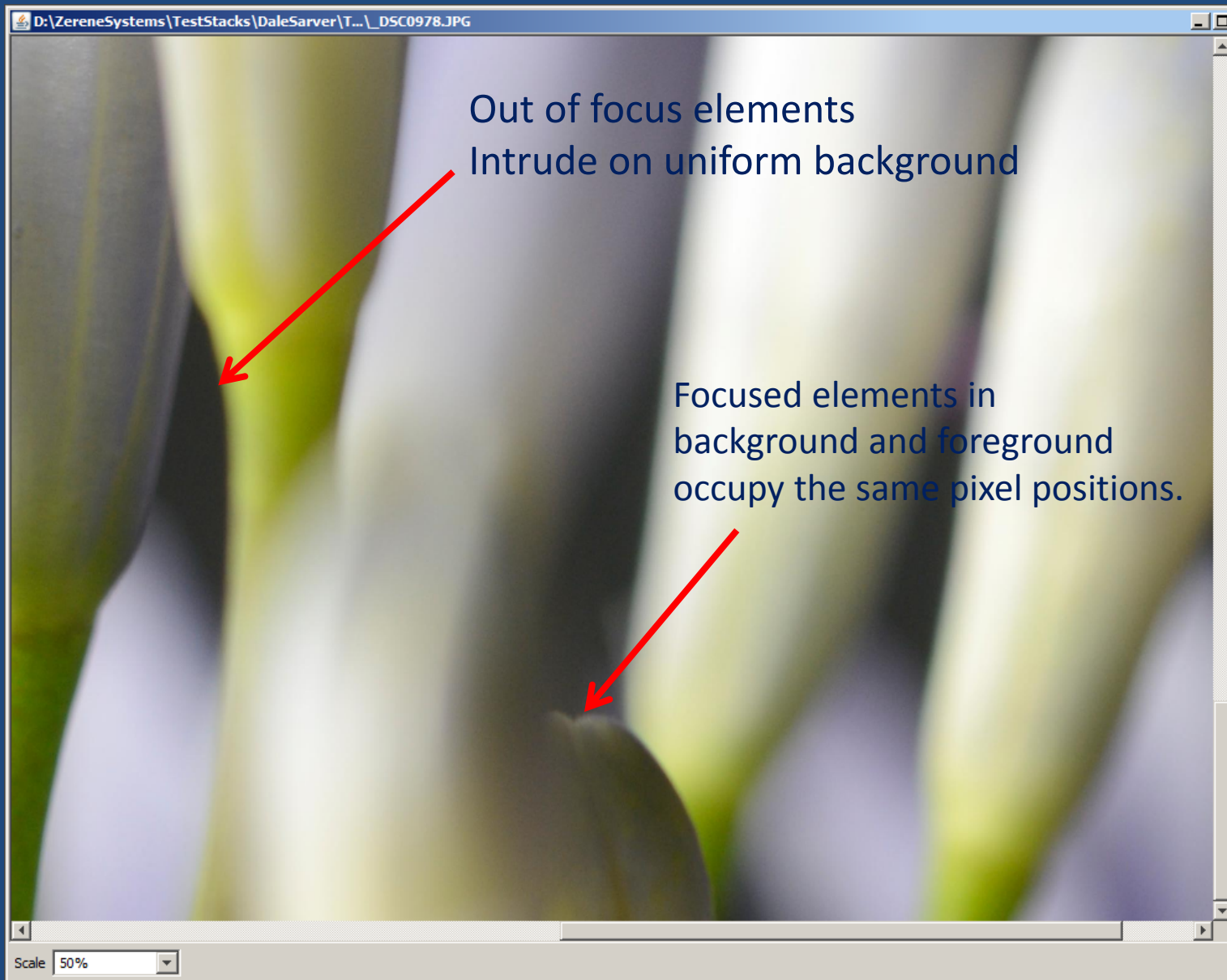
The Sequence Shows a Different Story



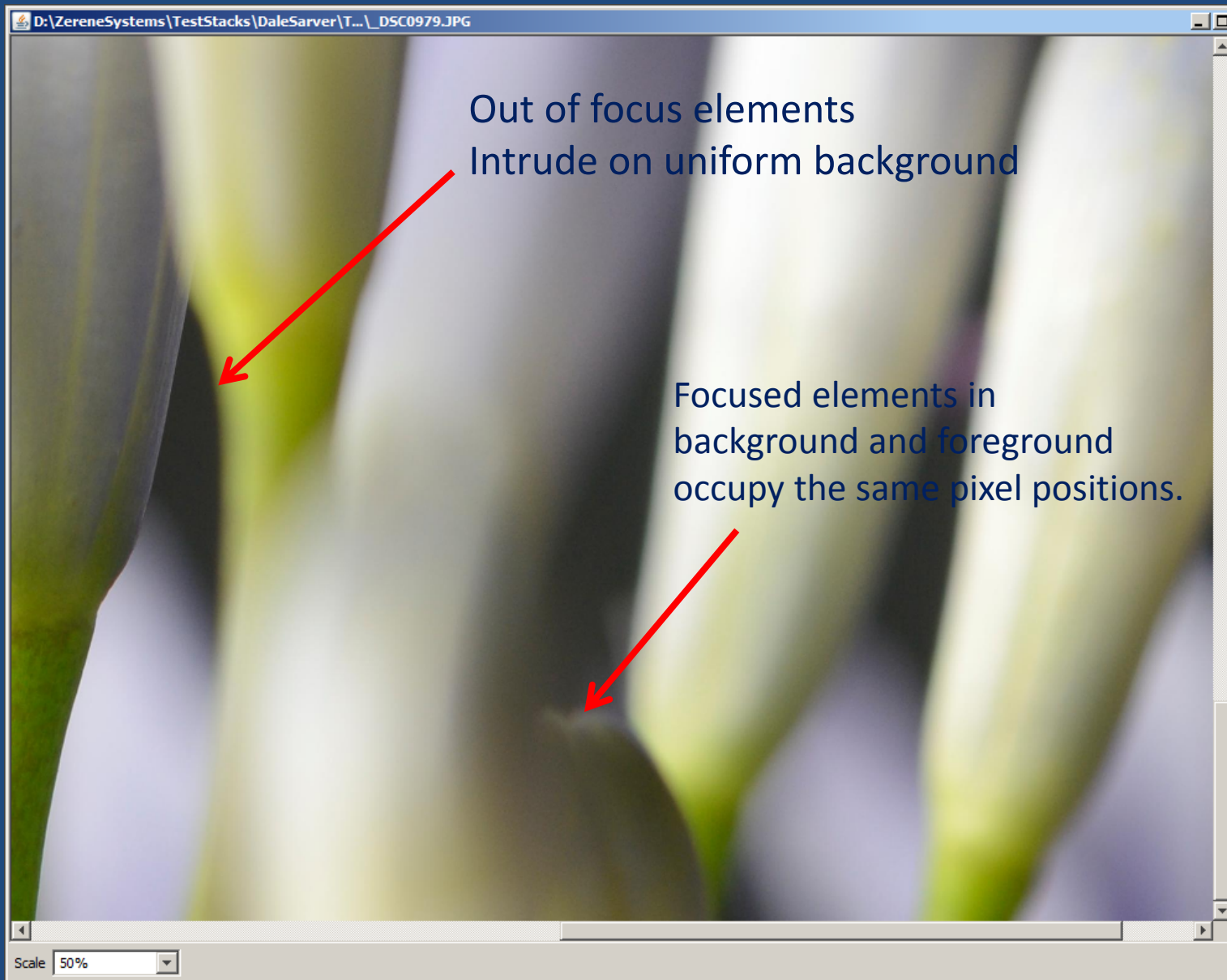
The Sequence Shows a Different Story



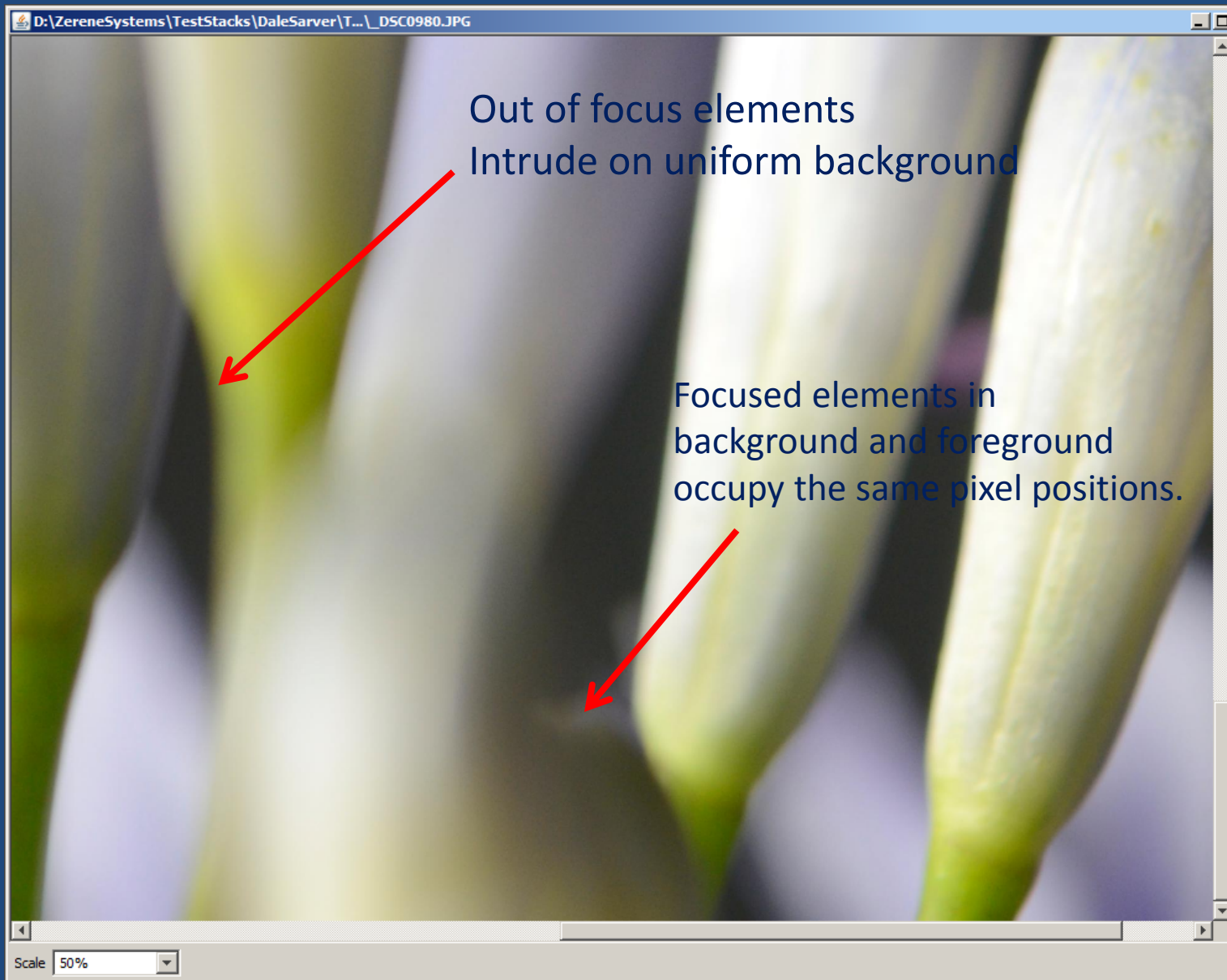
The Sequence Shows a Different Story



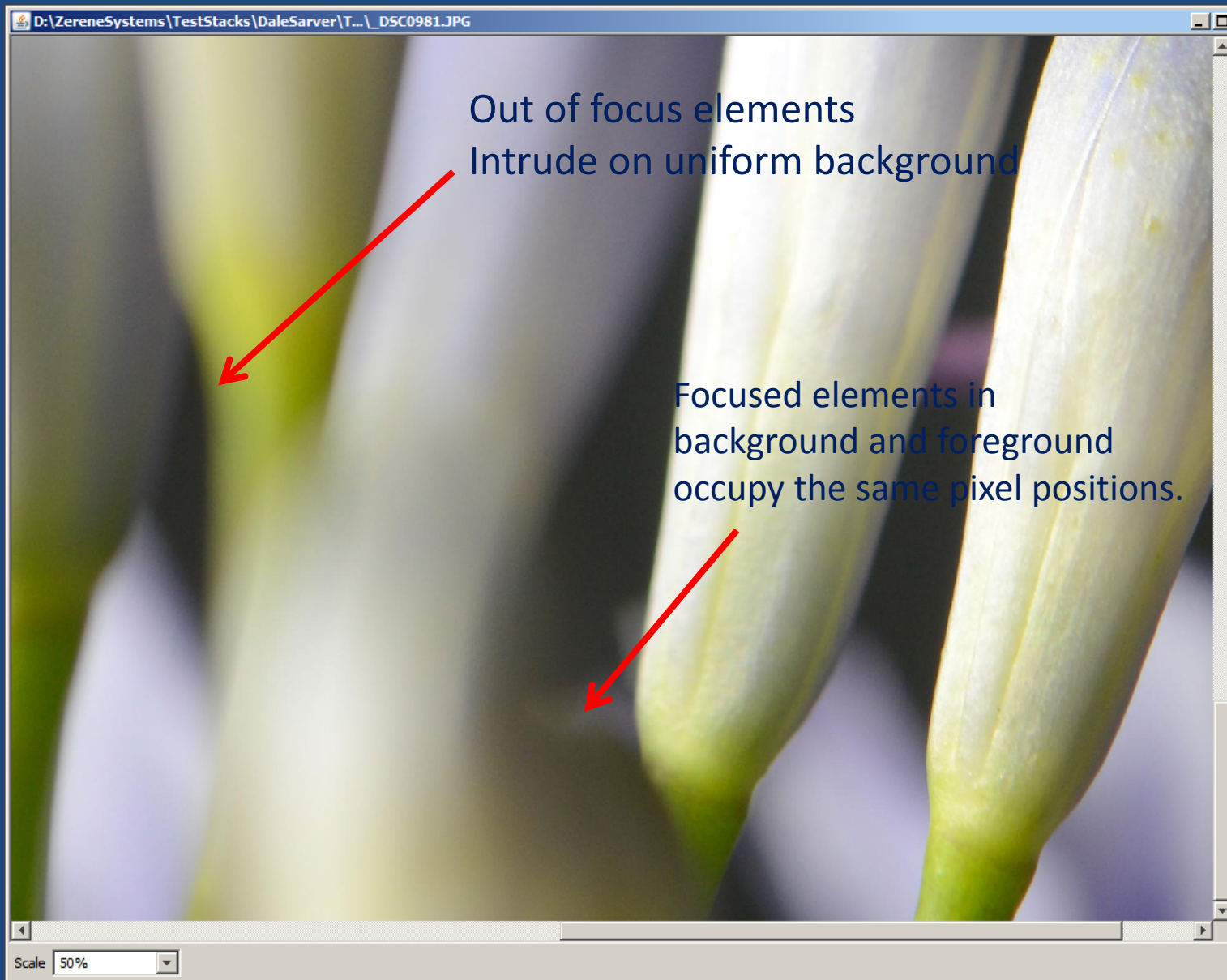
The Sequence Shows a Different Story



The Sequence Shows a Different Story



The Sequence Shows a Different Story



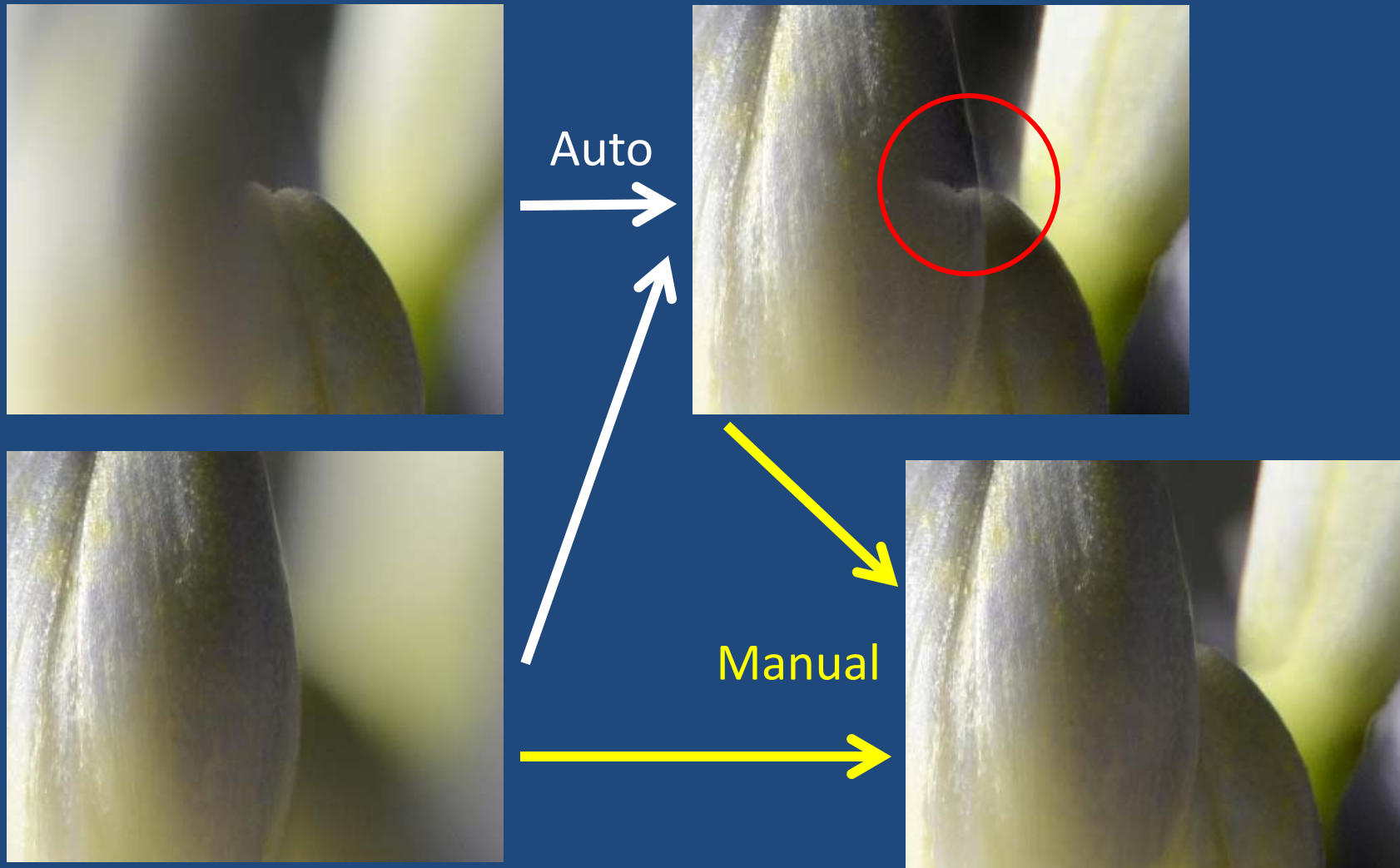
More About Those Last Few Problems...

- Transparent Foreground
- Halos (dark light bands)
in uniform background

Transparent Foreground

Cause: lens looks around foreground to see high contrast background

Solution: retouching

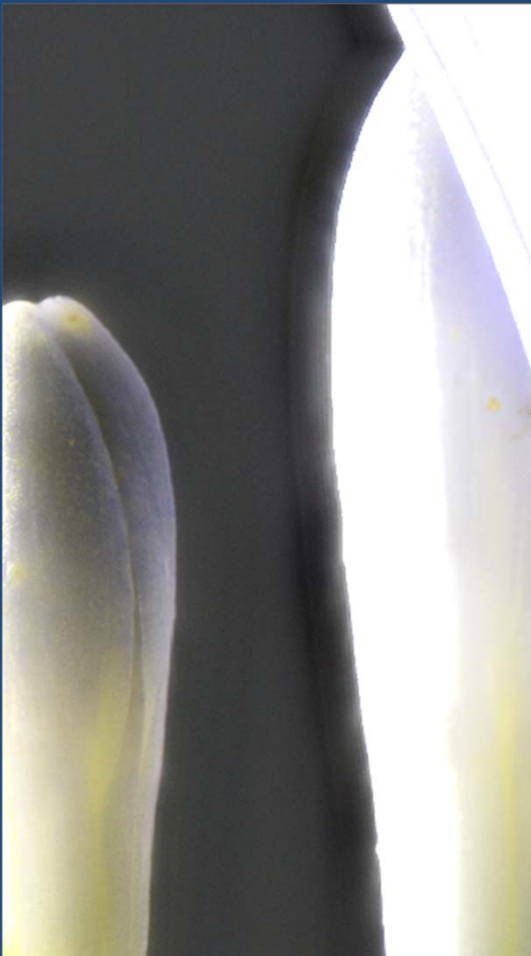


Dark/Light Bands in Uniform Background

Cause: software limitation – tries to preserve “detail” where there isn’t any!

Solution: human guidance – contrast threshold slider, external mask

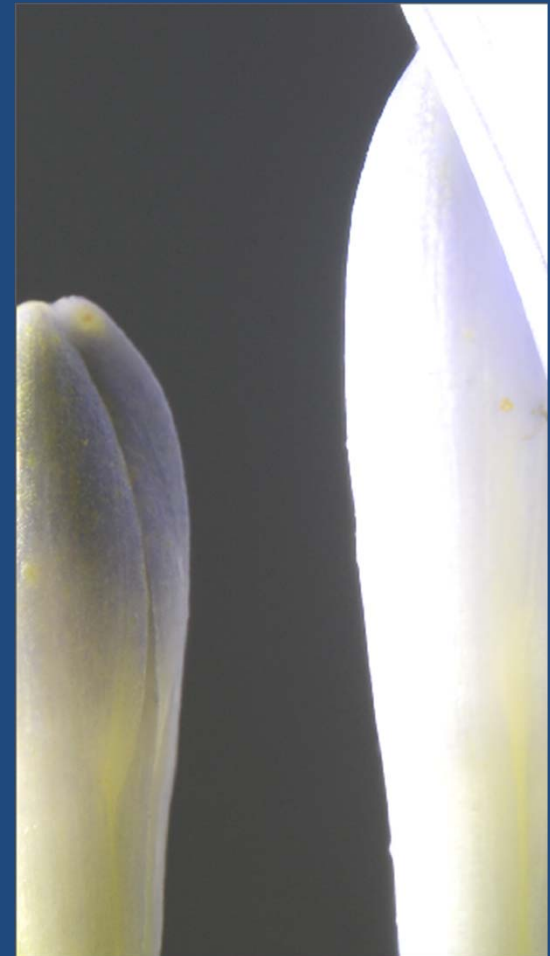
PMax



DMap (no guidance)



DMap (external mask)



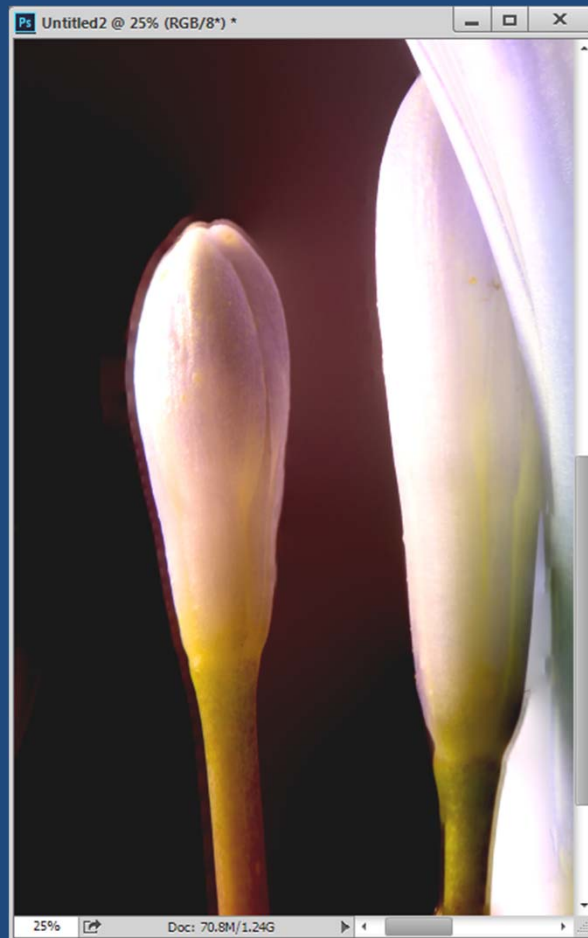
Images are brightened to emphasize halos.

Photoshop with the Difficult Stack

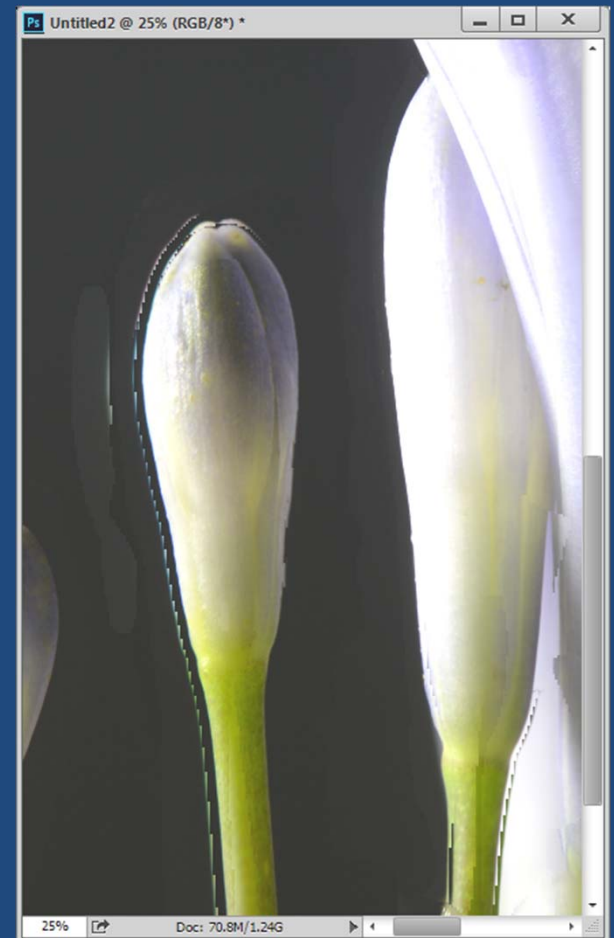
Auto align,
seamless tones & colors



Collage align,
seamless tones & colors



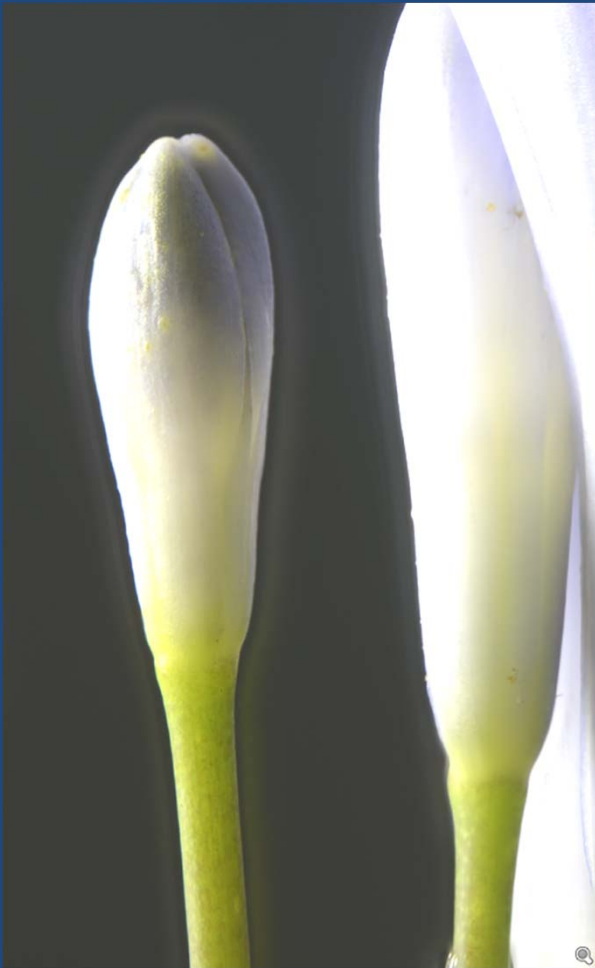
Collage align,
un-check "seamless..."



Images are brightened to emphasize halos.

Helicon Focus with the Difficult Stack

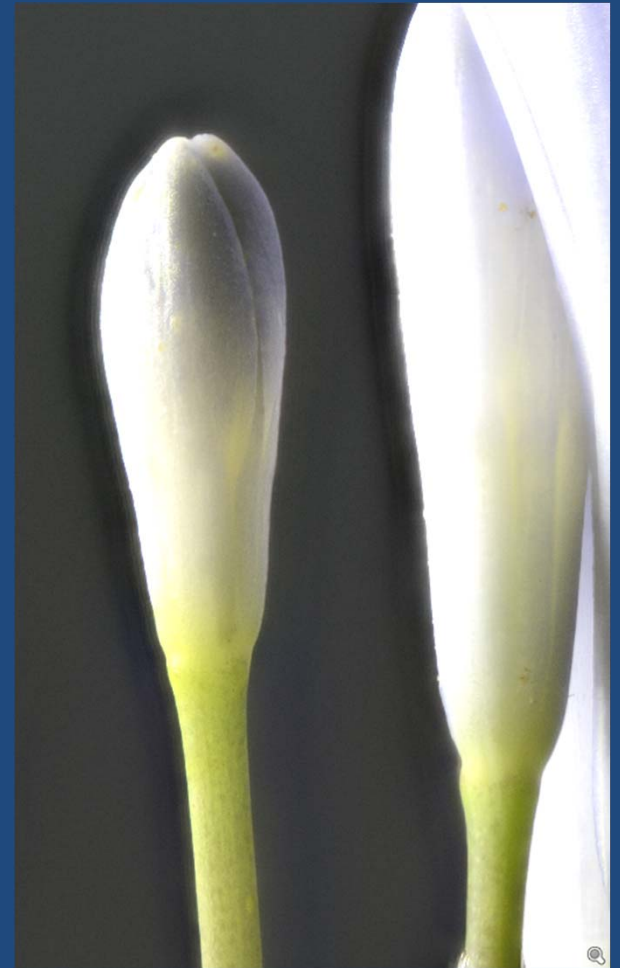
Method "A"
(weighted average)



Method "B"
(depth map)



Method "C"
(pyramid)



Images are brightened to emphasize halos.

The Final Result – Zerene Stacker



Some More Examples Of Focus Stacking

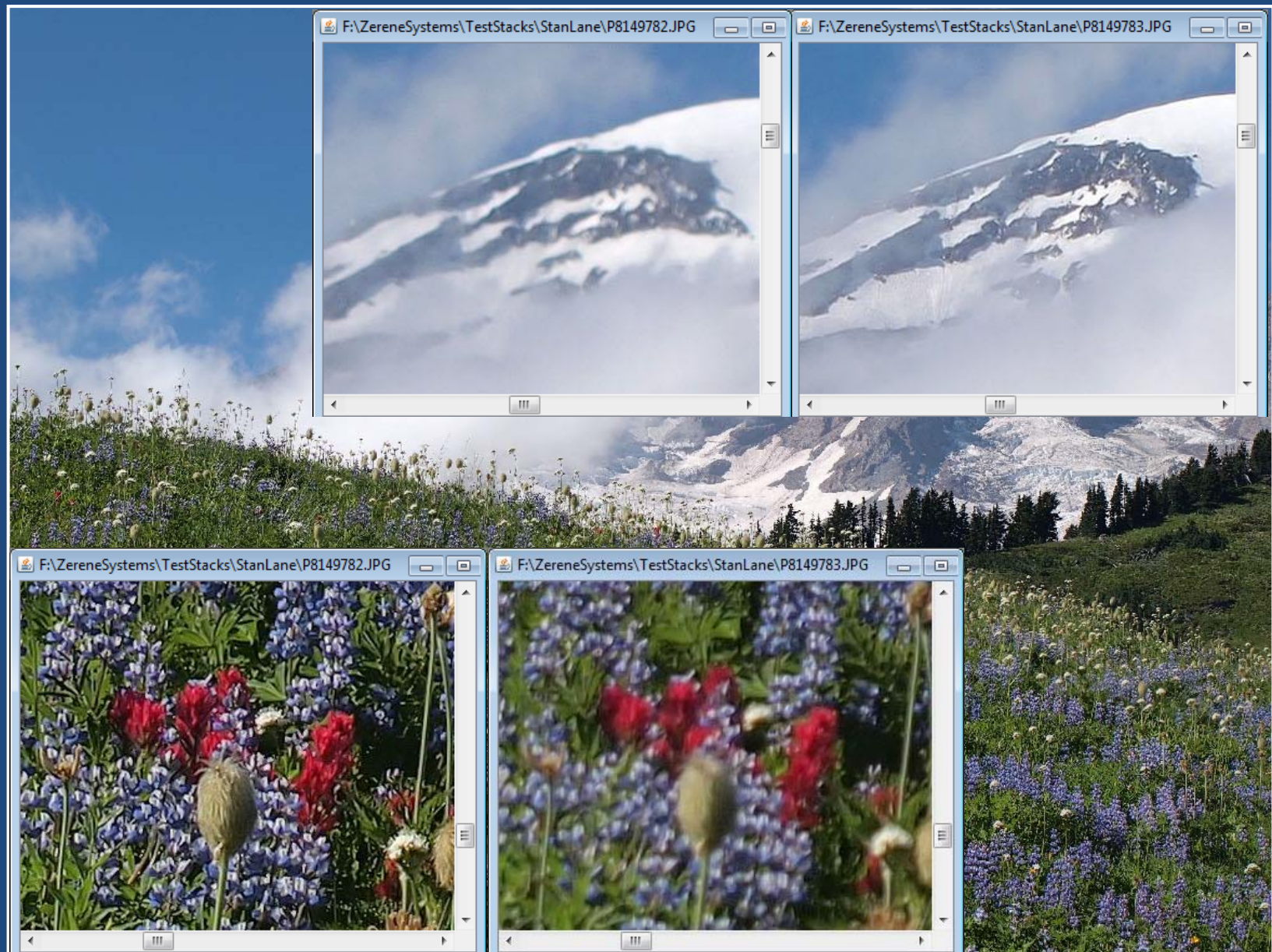


Mt. Rainier, 3 Frames



Image by Stan Lane

Showing The Focus Variation

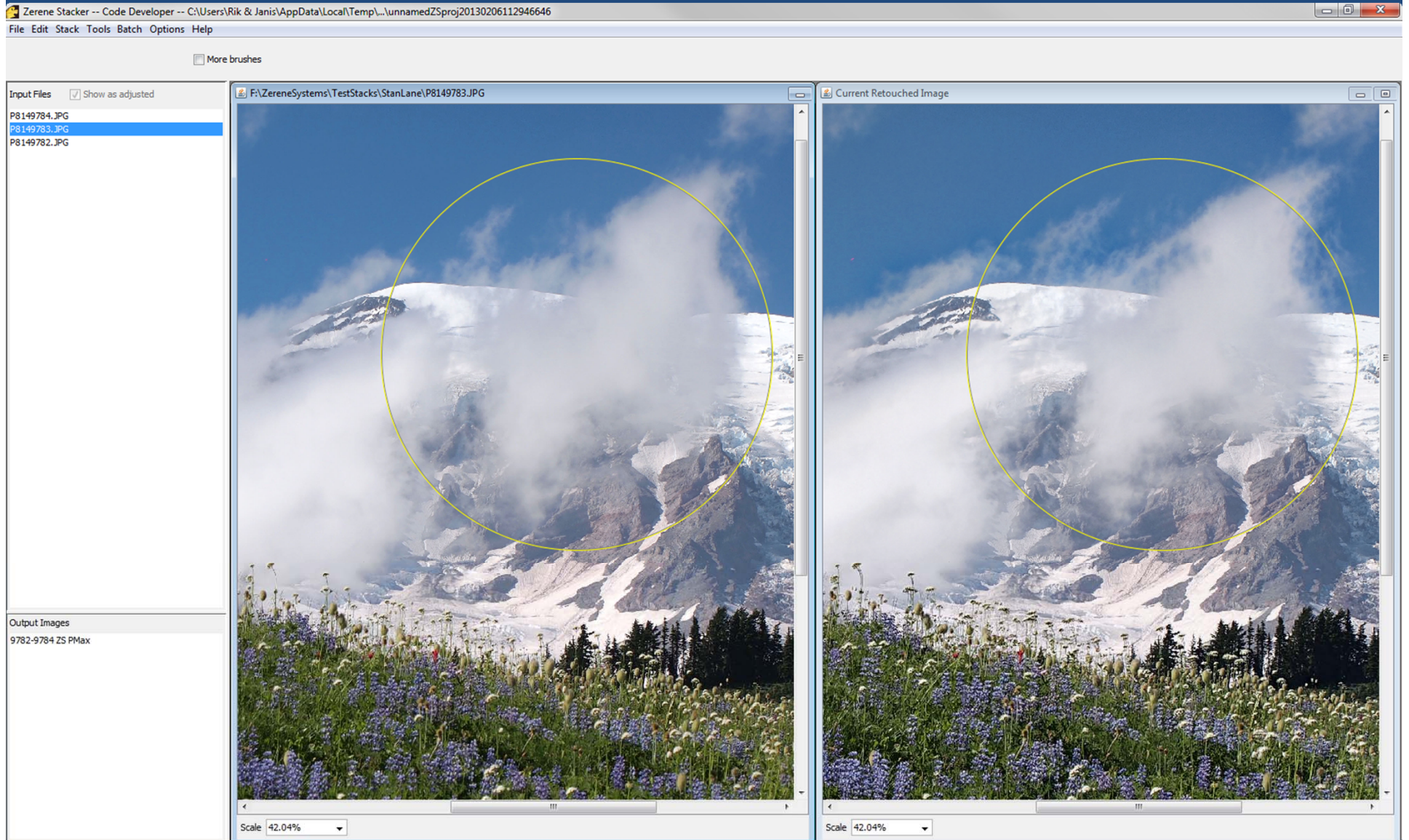


First Output Shows Motion Artifacts

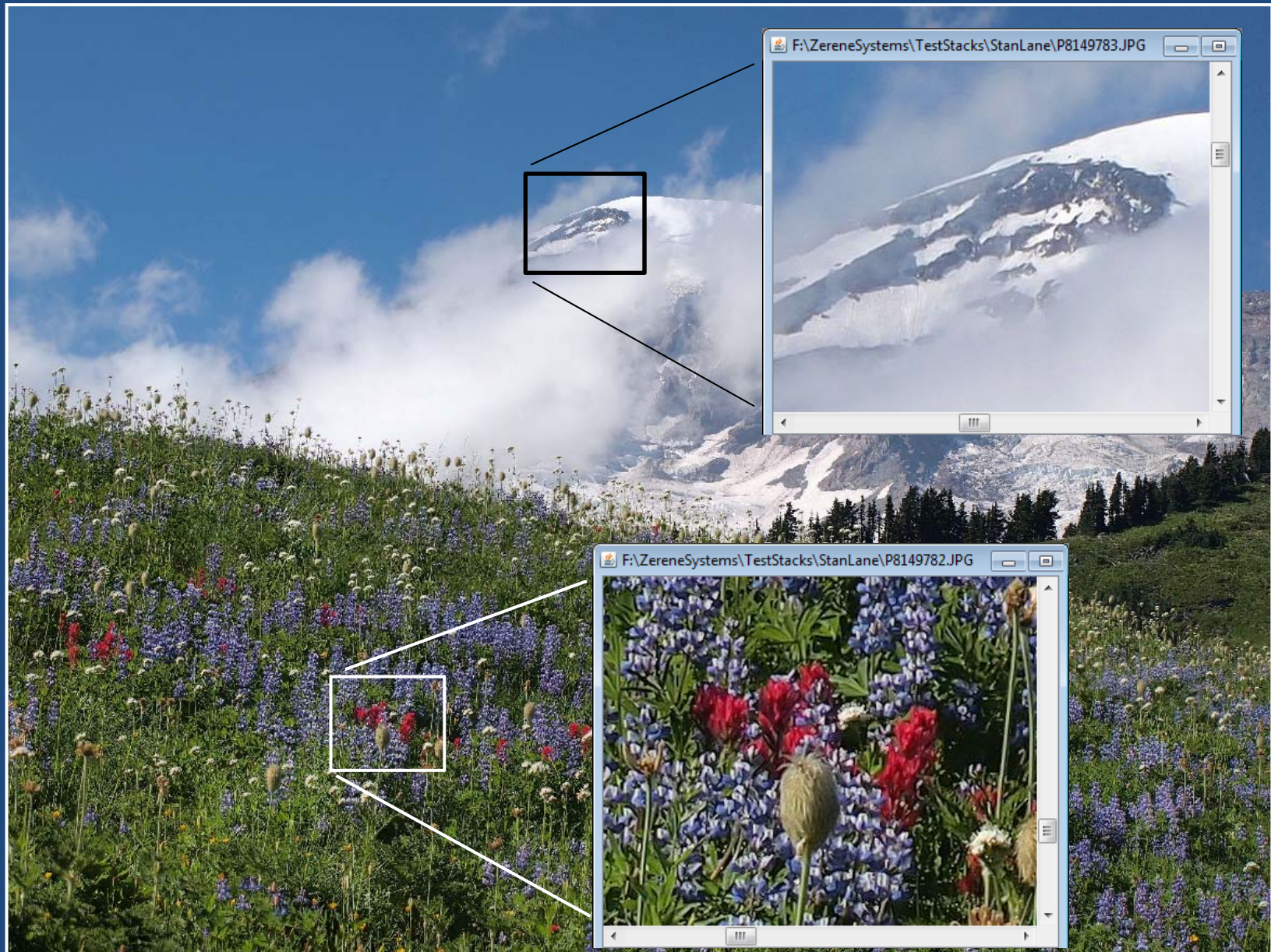
C:\Program Files\ZereneStacker\9782-9784 ZS PMax



Fixing The Sky By Retouching



Finished Composite – Sharp Everywhere



Mt. Rainier, 3 Frames



Image by Stan Lane

Apparently Routine Closeup: DOF Control



From “The Art of Focus Stacking”, Michael Erlewine, <http://macrostop.com>

A Similar Example: Some Forget-Me-Nots



Bart van der Mark, <http://www.flickr.com/photos/bartvandermark/4586315503/sizes/o/in/photostream/>

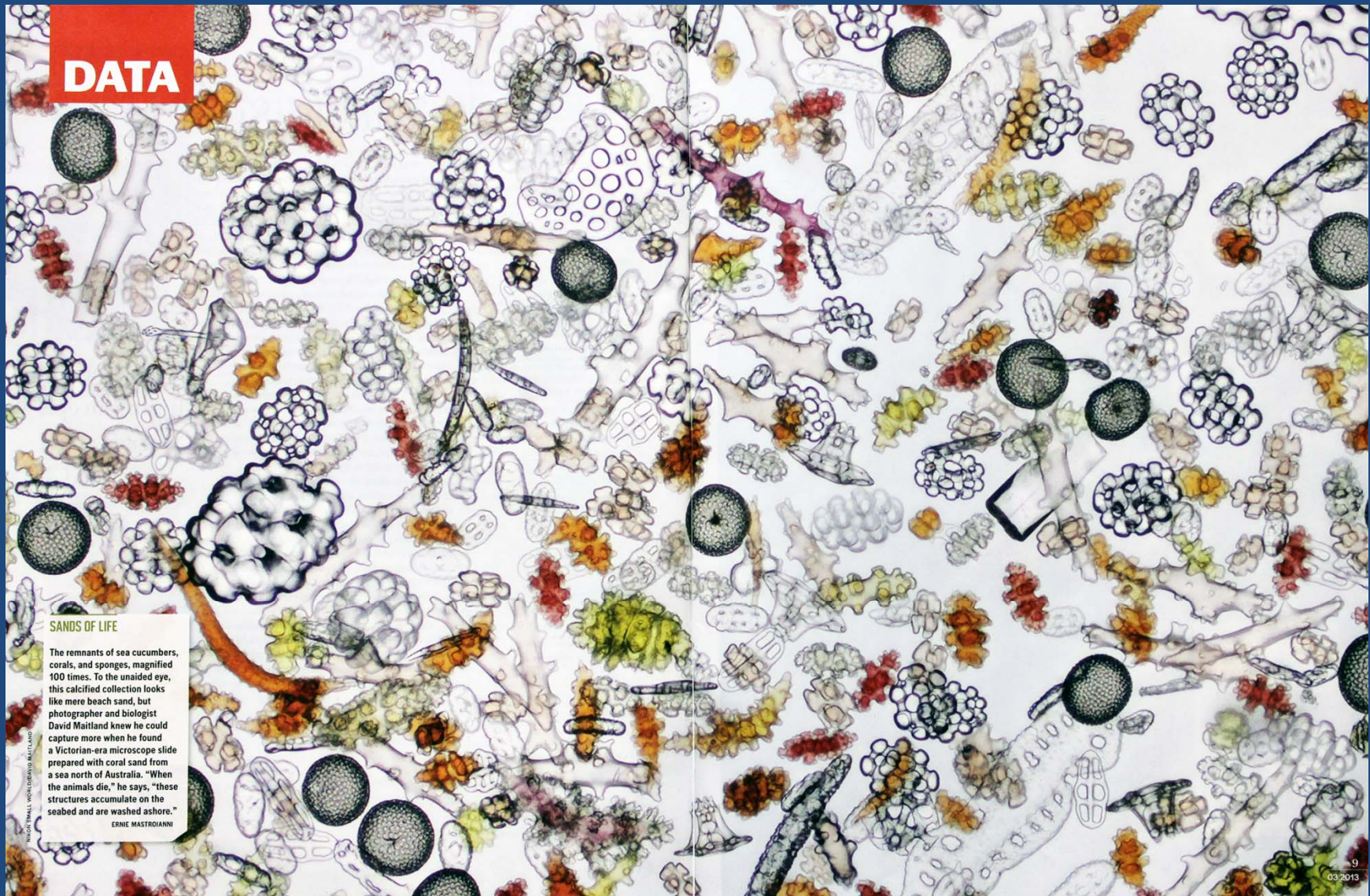
“Extreme Macro”



John Hallmén in Sierra Magazine.

See more at <http://www.morfa.se>

Microscopy



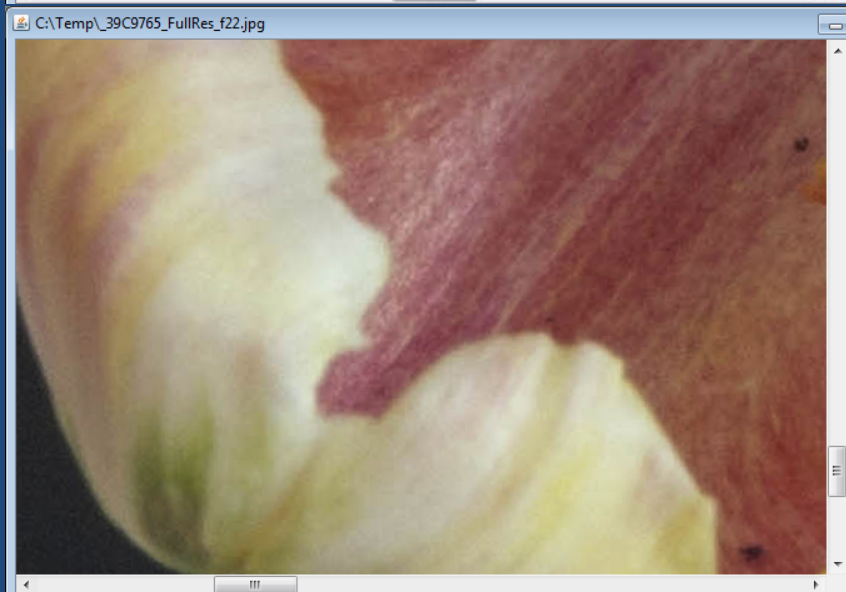
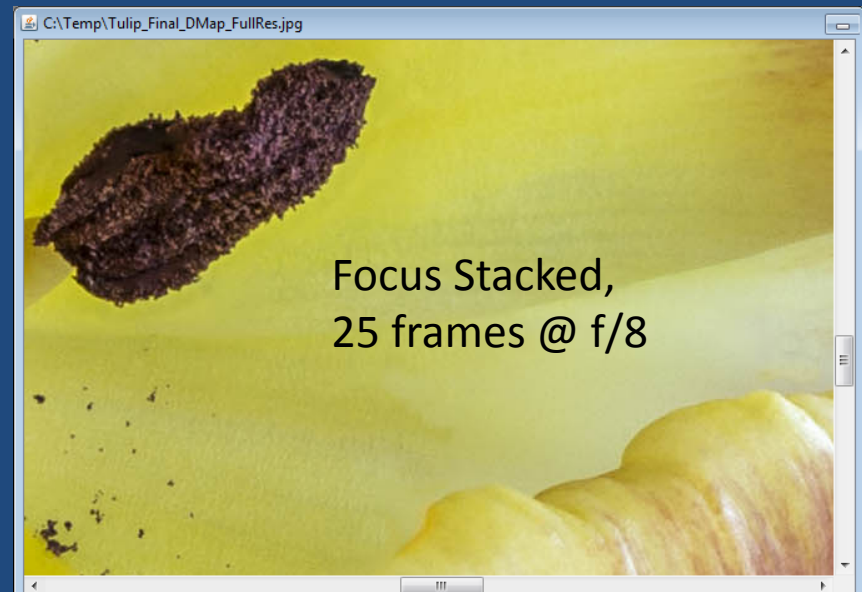
David Maitland in Discover Magazine, from
<http://www.nikonsmallworld.com/galleries/photo/2012-photomicrography-competition>

One Last Example...



© George D. Lepp 2013

Which Would You Rather Have?

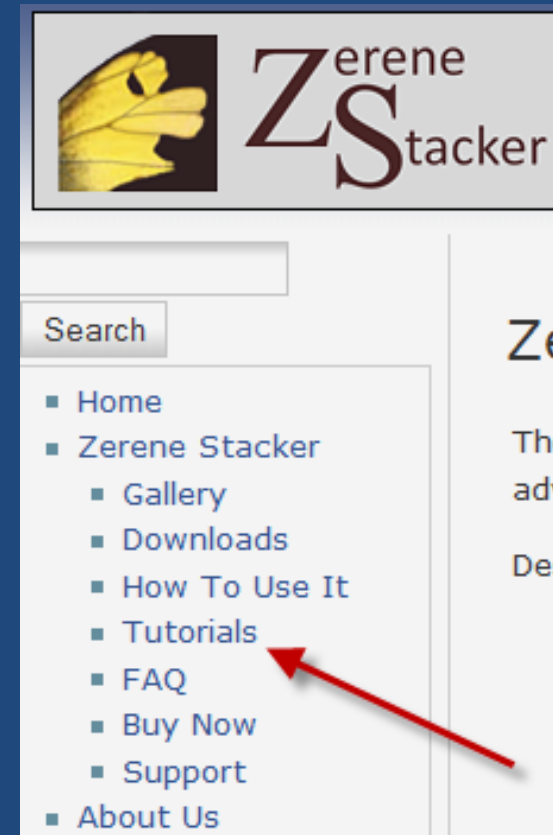


Images courtesy George D. Lepp, 2/7/2013

To See The Slides Again...

This slide set can be found at
<http://zerenesystems.com>

It's in the "Tutorials" section,
linked at the bottom of page.



Recommended Presentation Slide Set

- "Introduction to Focus Stacking", presented as a 1 hour course

Recap & References

- Focus stacking gives sharp images and large depth of field
- Recommended software:

Zerene Stacker, <http://ZereneSystems.com/stacker>

- Web forum dedicated to photography of small things

<http://www.photomacrography.net>

- For more information

email: support@ZereneSystems.com

The end...

Reserve Slides...

Zerene Stacker License Editions

- **Computers:** Windows, Macintosh, Linux, 32- and 64-bit, every license works on all platforms, mix & match is OK.
- **Upgrades:** just the difference in license price.
- **Updates:** free.
- **30-day Free Trial:** fully functional, all features, no restrictions, no registration needed.
- **Professional:** \$289, allows unlimited sale of images, includes all advanced functions such as Lightroom plug-in, faster processing, built-in controls for StackShot.
- **Prosumer:** \$189, hobbyists only, same features as Professional.
- **Personal:** \$89, hobbyists only. Provides all key functions including retouching and 64-bit mode.
- **Student:** \$39, same features as Personal.

Where I Fit In...

- 1) Manage & edit a strictly non-commercial website dedicated to the photography of small subjects.
- 2) Develop & document ideas for techniques and equipment.
- 3) Design, code, document, and support Zerene Stacker.



Focus Stacking is Now Accepted by National Geographic...



What Is That Thing?

By Charles C. Mann

Photographs by Anand Varma



In 2007 headlines shouted about “colony collapse disorder,” a frightening new phenomenon that was wiping out hives around the world. Most researchers now believe that it is actually a deadly mix of pests, pathogens, pesticides, and habitat loss. The single worst element is *Varroa destructor*, a pinhead-size Asian mite, shown here atop a bee pupa.

It's a *Varroa* mite, one cause of colony collapse disorder.

Macro Landscape Using Compact Camera

Canon A710
hung upside down
under a tripod



Macro Lens on Geared Tripod Head



Tabletop setup: macro rail & lens



More options...a hand-driven screw table



John Hallmén at <http://www.photomacrography.net/forum/viewtopic.php?t=15711>

Producing An Image Like This



John Hallmén, <http://www.johnhallmen.se/studio-stacks/3xixzx6bjwv1cichn9dyw6zxmrnwt6>

My Personal Passion Is Small Things

This is a common “bluebottle” fly.



0.001 mm resolution,
3.75 mm depth of field
“looks like SEM, but with natural colors”

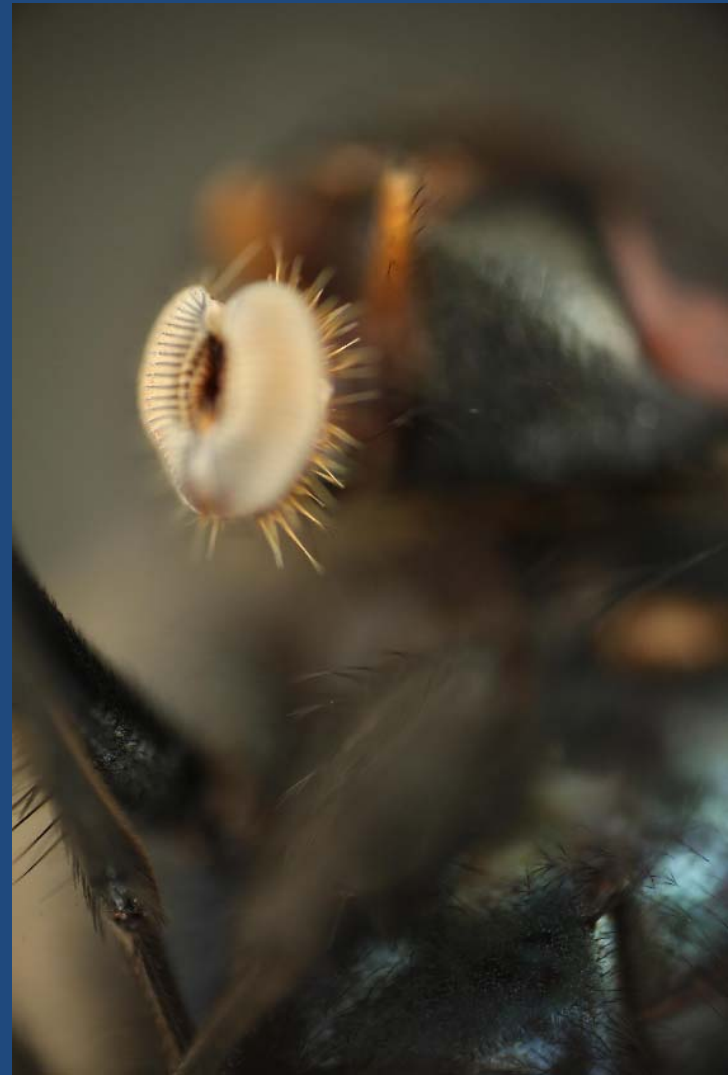


For small things, focus stacking is critical

Stacked composite



What You Can See At One Moment



Here's The Setup That Shot The Fly



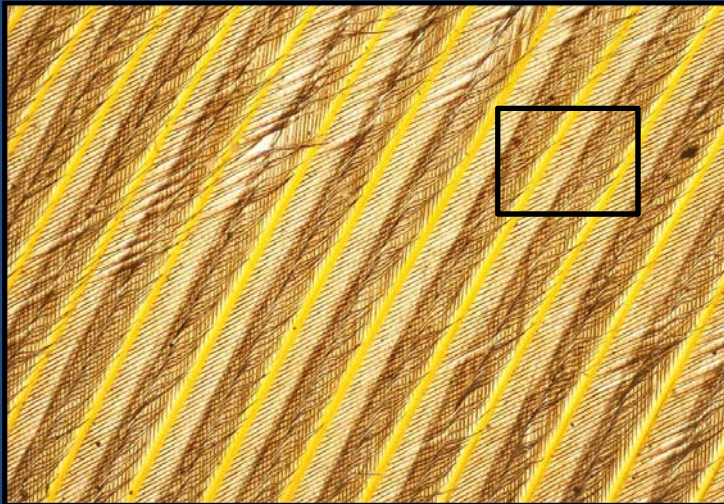
- “StackShot” automated rail
- Canon T1i camera
- Nikon microscope objective
- Vivitar telephoto (“tube lens” for objective)
- Canon 580 EX II flash
- Manfrotto 819-1 arm
- Adorama 2-axis rail
- Giottos mini ballhead
- Slik 504QF II tripod
- Cut, drilled & painted 2x4 wood

Feather On A Table

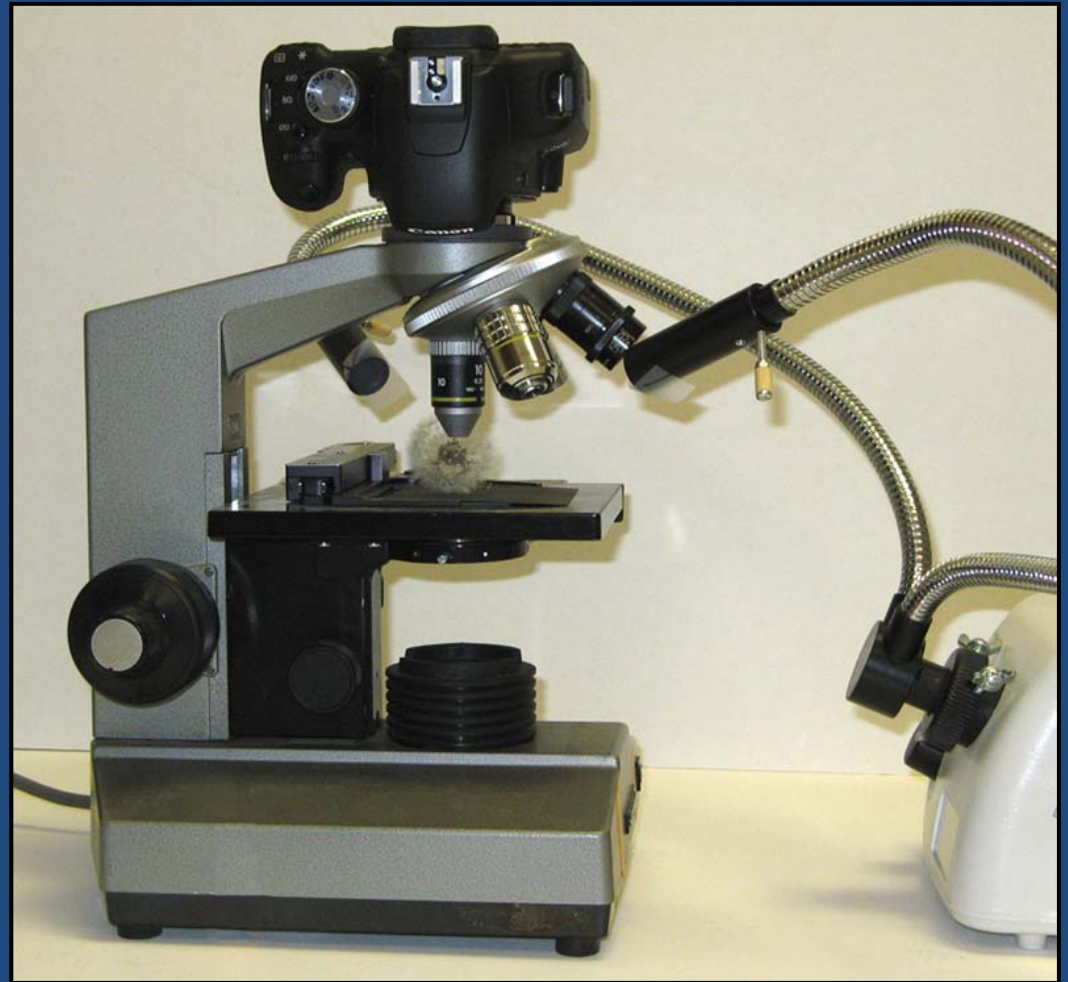


62 frames, shot at 5X on sensor
using A/F motor focusing
with microscope objective
4.4 mm total field width

This crop, $\frac{1}{2}$ mm = $\frac{1}{50}$ inch



Shooting Through a Microscope



Manual focus step to $0.5\ \mu\text{m}$
(one wavelength of green light)

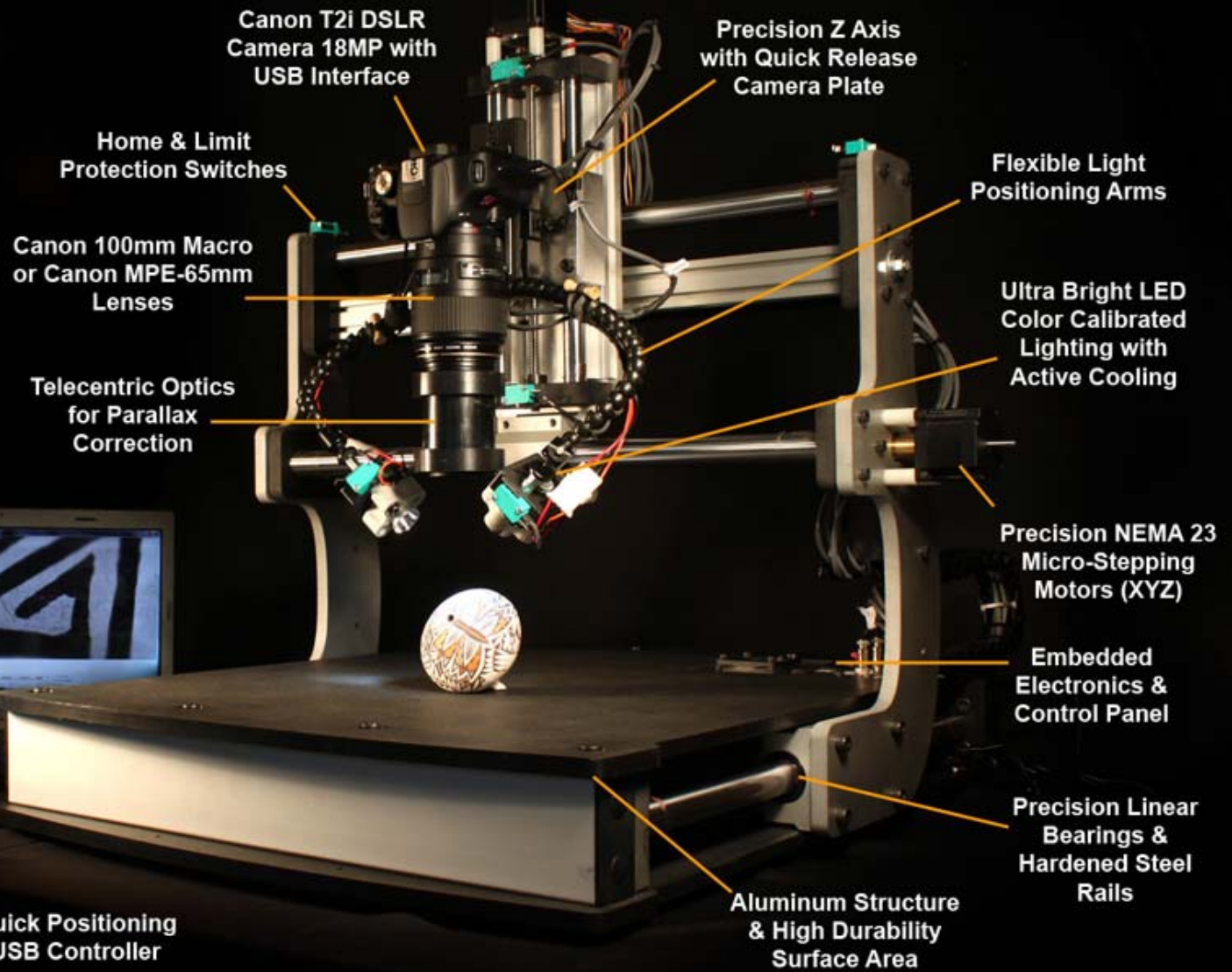
Visionary Digital's BK Plus System



GIGAmacro's package deal

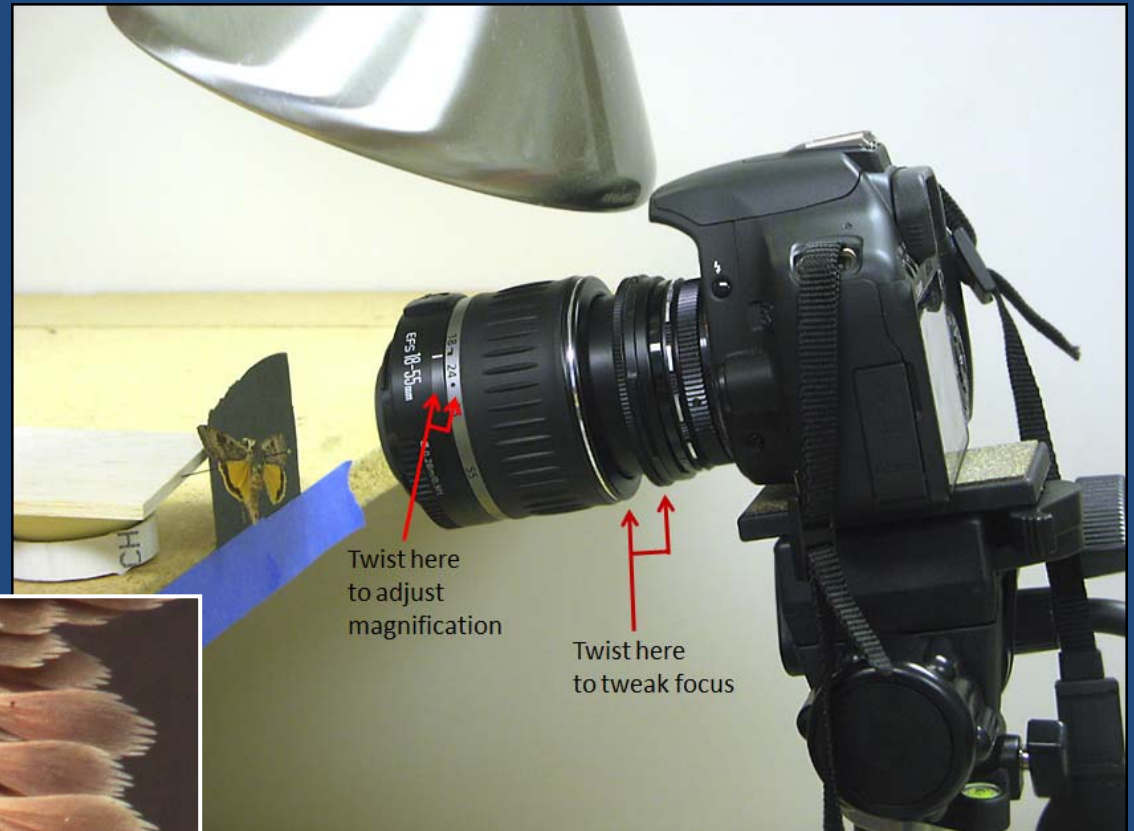
GIGAmacro Professional Imaging System

Released Nov 2011
Four Chambers Studio
GIGAmacro.com



Or Reverse a Standard Zoom Lens

This is a shockingly simple and cheap way to get high magnification with useful quality.



Fotodiox reverse adapter,
\$7.95 and free shipping
at [Amazon.com](https://www.amazon.com)

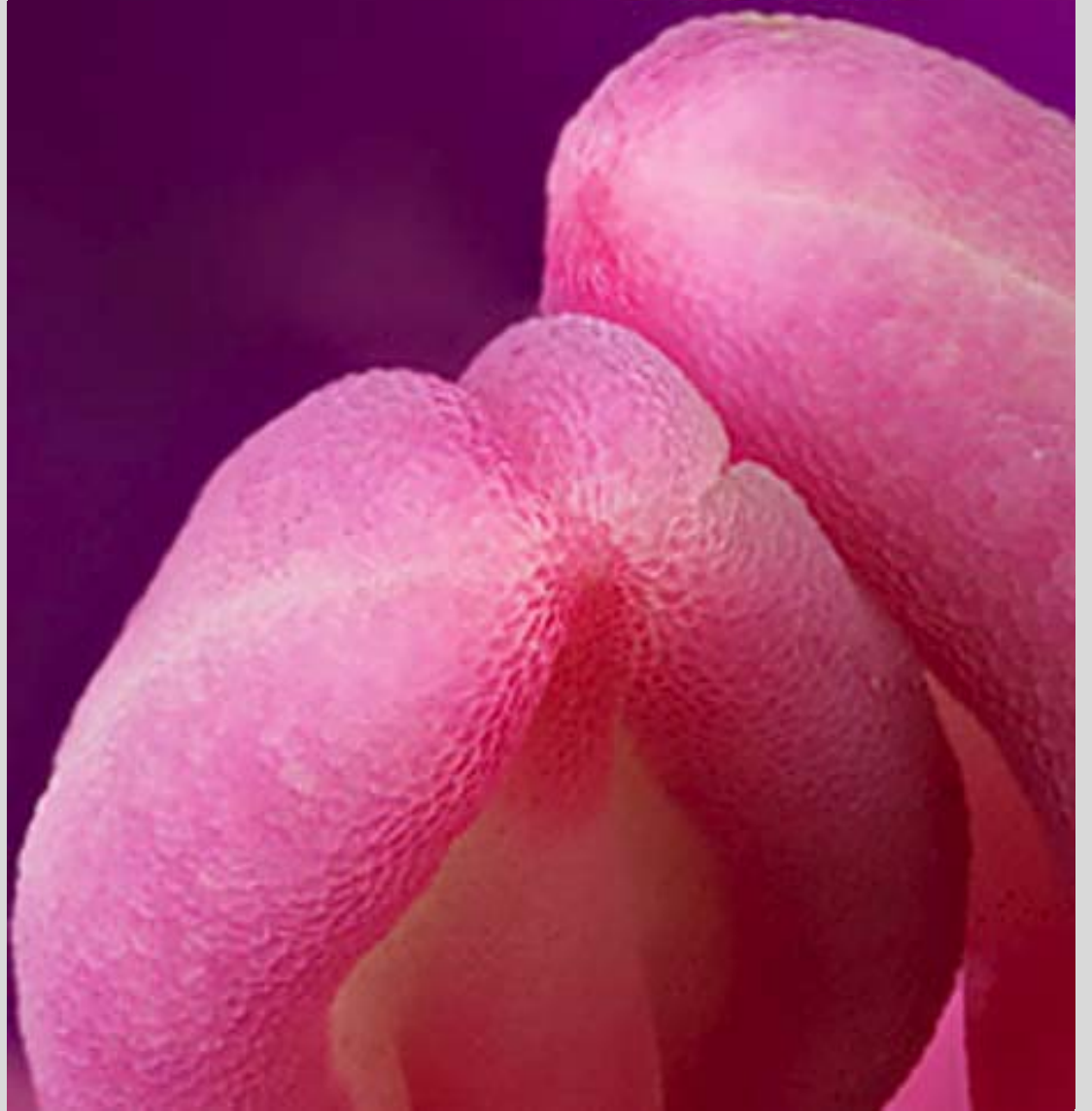
Low-tech approach



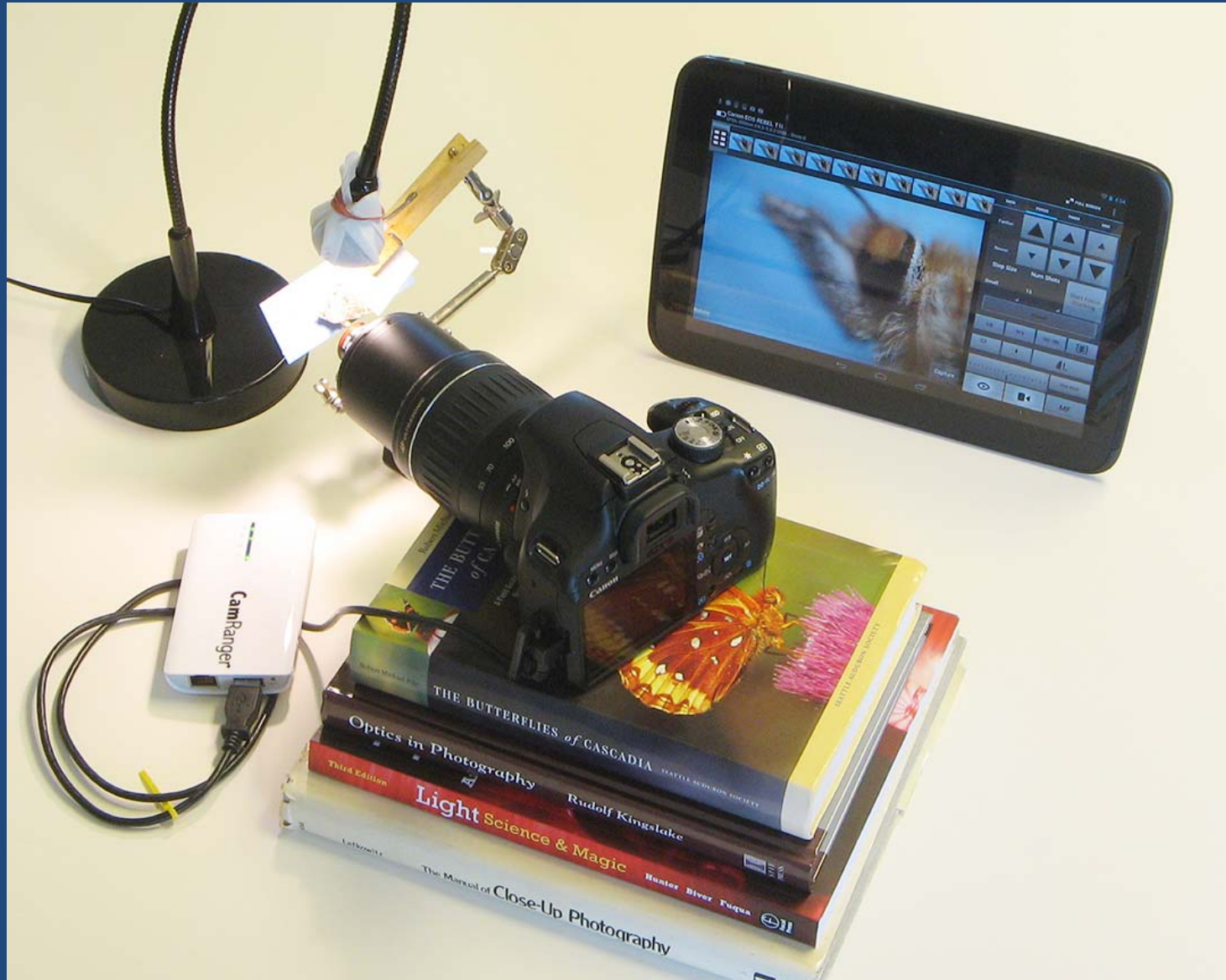
“Typical setup I use for flower bits shots”

Brian Valentine (username “LordV” on Flickr)

Brian's result: "Fuchsia Anthers"



Macro Stacking with the CamRanger



The Result (one frame)...



The Result (stacked from 71 frames)...



Closer...and rocking (from 1 stack)



Closer...and rocking (from 1 stack)

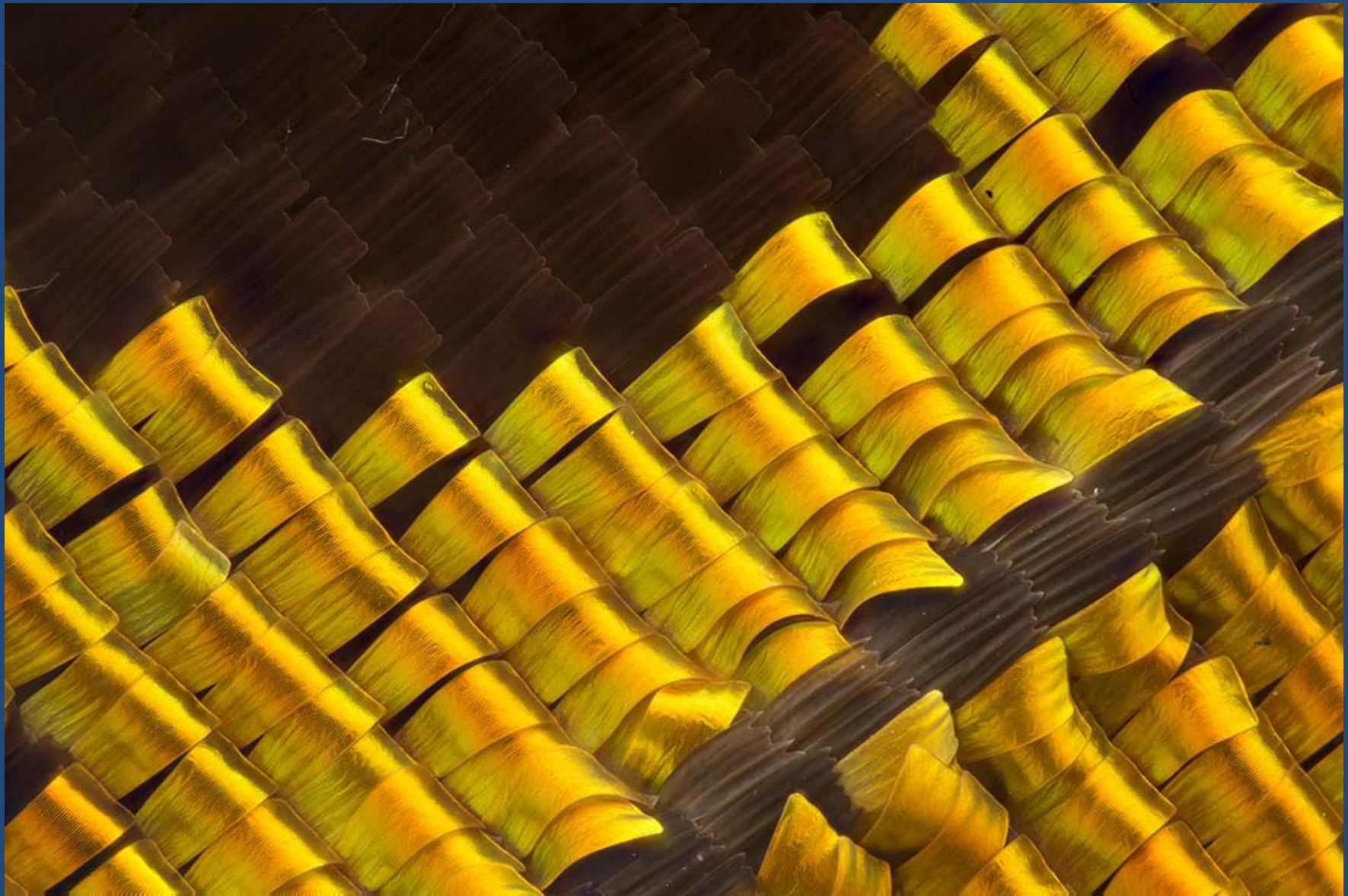


Closer...and rocking (from 1 stack)



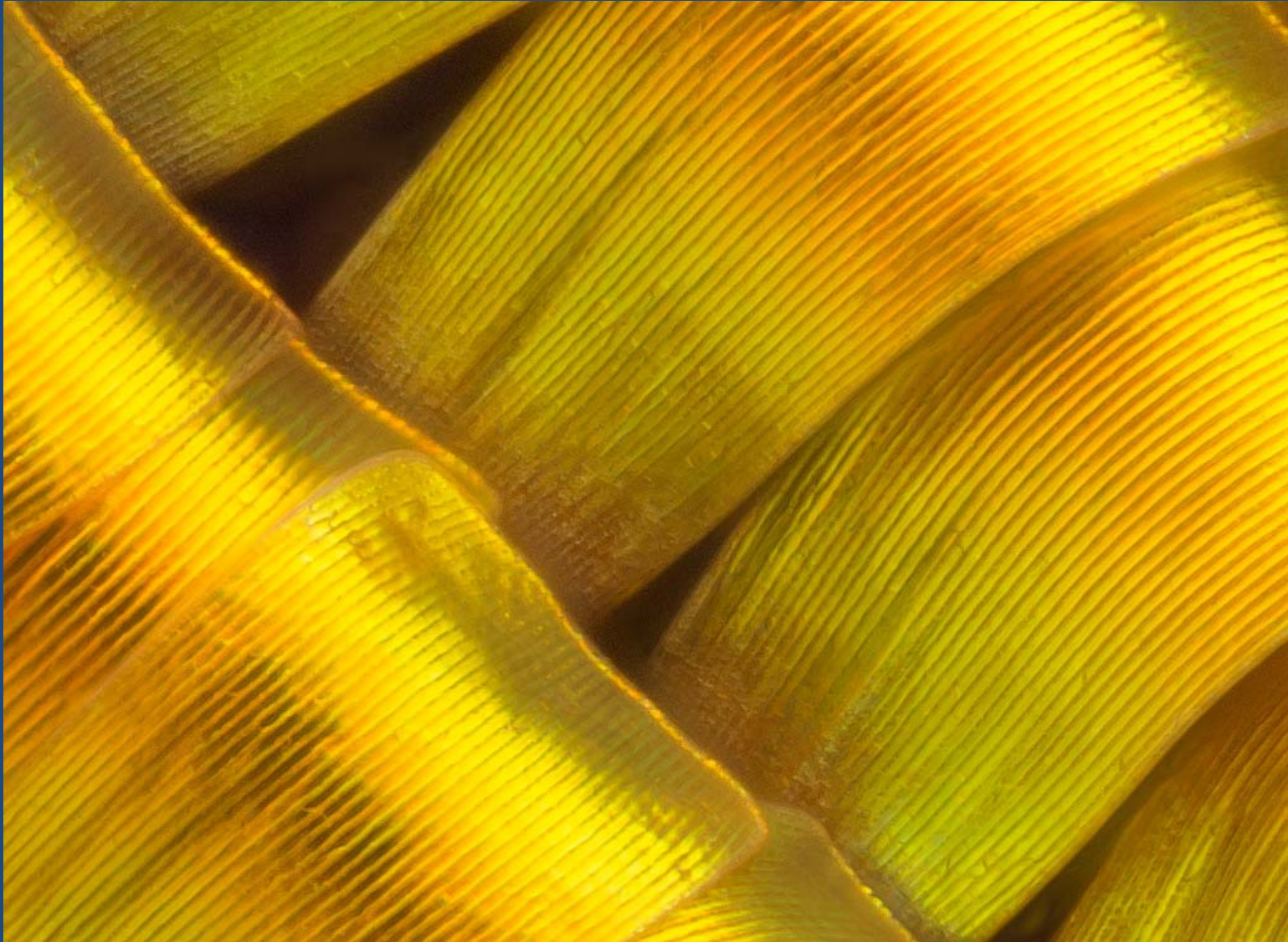
Wing Scales of Sunset Moth

(*Chrysiridia rhipheus*, 20X objective, 128 frames @ 0.002 mm)



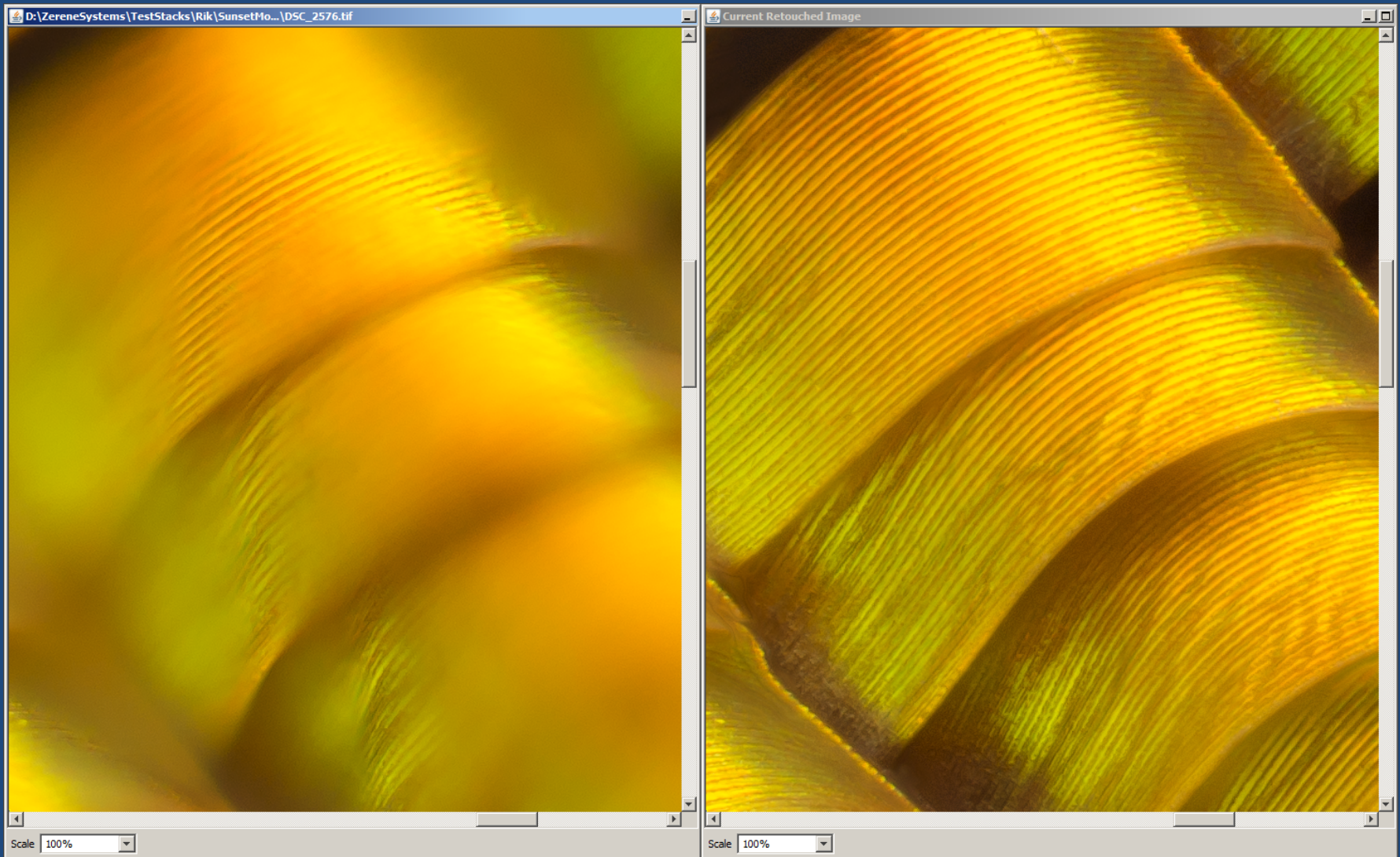
A Closer View of Those Scales

(about "500X")



Single Frame versus Stacked

(Sunset Moth: *Chrysiridia rhipheus*, 20X objective, 128 frames @ 0.002 mm)



photomacrography.net has lots of descriptions of setups for macro/micro work

rjlittlefield
Site Admin



Joined: 01 Aug 2006
Posts: 11876
Location: Richland,
Washington State, USA

Posted: Sun Feb 07, 2010 10:49 pm Post subject: List of links in FAQ: What's the best way to focus?

quote edit IP

Additional links to setups and discussions for high magnification work:

Charles Krebs: [Tabletop "macro" setup](#).

Many contributors, covering [Nikon](#), [Olympus](#), [Meiji](#), [Swift Focus Blocks & Setups](#).

Chris S: ["Bratcam" \(focus blocks and goniometers\)](#)

Chris S: [A field rig \(a bit of the Bratcam\)](#)

LordV: [sliding by hand on glass table mat](#) (more [HERE](#))

liuto: [Proxxon table and linear stages](#)

rjlittlefield: ["afocal" setup through microscope](#)

rjlittlefield: [bellows on microscope base](#)

RogelioMoreno: [infinity objective on telephoto lens](#)

seta666: [linear stage with micrometer drive, mounted on mini tripod](#). For part numbers, visit the Flickr link and hover over parts of the image.

Pau: [vertical macro setup](#), using salvaged microscope for fine focus.

januszj: [horizontal setup](#), using microscope base including the stage for focus and specimen holding.

Tomatito: horizontal setup using Lego blocks for structure (see [HERE](#), images 5-6) and Proxxon precision vise ([HERE](#), image 2) for subject movement.

Keks: an "all directions" setup using the StackShot, [HERE](#).

Marc Iwaniec, Thorlabs stages and goniometers, [HERE](#).

Wil Milne: extending the stage of a microscope base, [HERE](#).

John Hallmén: simple off-the-shelf stacking setup using Proxxon screw table, [HERE](#).

naturephoto1: studio macro rig with goniometers, focus block, and screw rail, [HERE](#)

Hokan: a Velmex rig, [HERE](#).

daemonoropsis, StackShot mounted on Arca/Swiss rails & breadboard, [HERE](#).

ecooper, Laboval 4 microscope body lying on its back, [HERE](#).

noah212, microscope turret on bellows, [HERE](#)

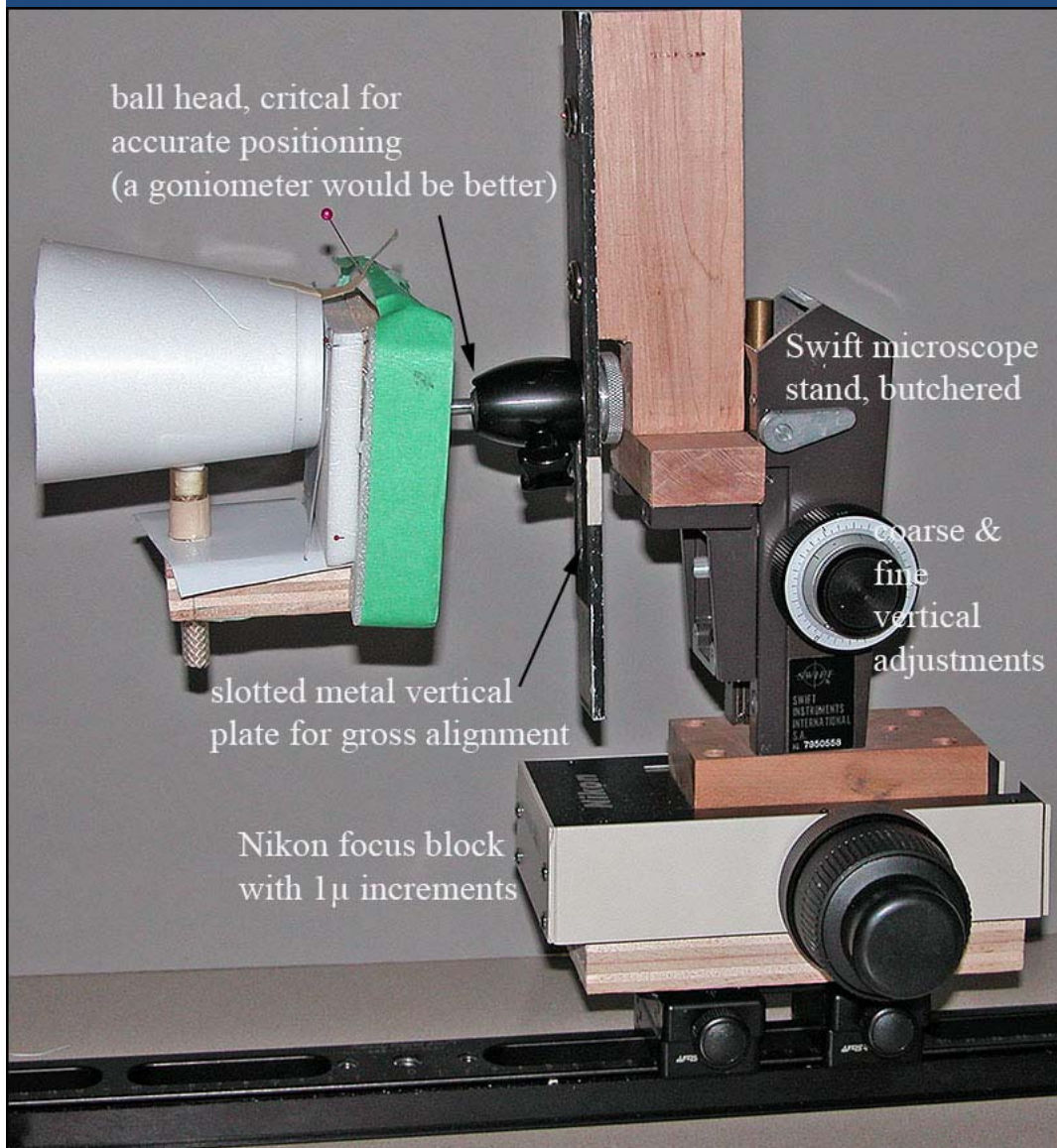
--Rik

Edited May 2, 2010, to add some more links.

Edited July 7, 2010, to add some more links.

“The solutions are frighteningly simple when you see what can be cannibalised and bolted together”

Chris Raper (new stacker)



Built and photographed by Dr. Tony Thomas

*As discussed at
<http://www.photomacrography.net/forum/viewtopic.php?p=94421#94421>*

The Bottom Line:

Just do whatever it takes
to get numerous images
from the same viewpoint
but in different focus planes

Remember These Examples...



Macro and Close-up Photography
Text and Photos by Michael Erlewine



Or This New One...



John Hallmén, field stack